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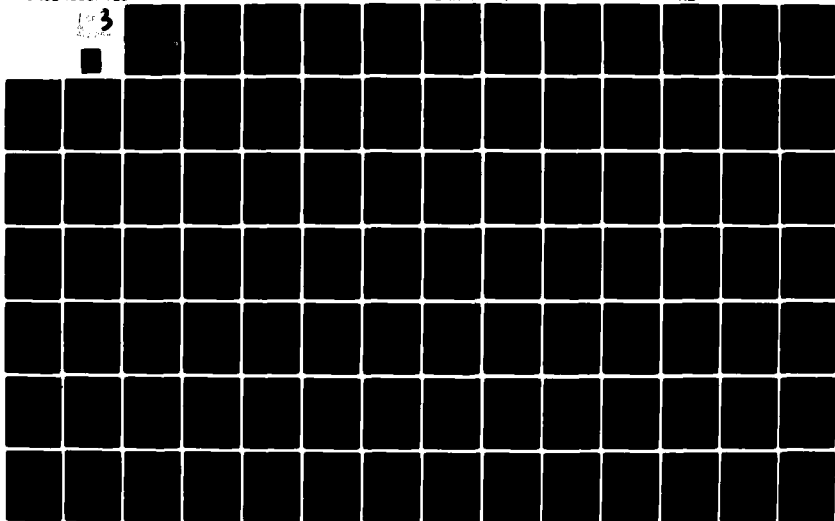
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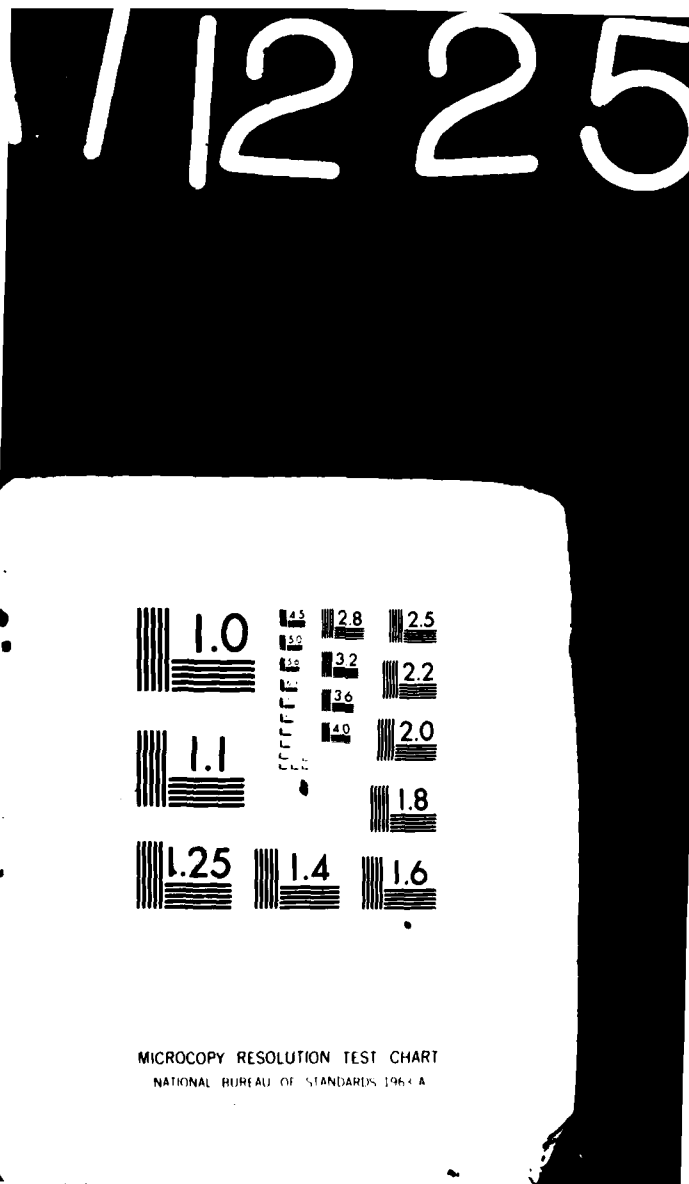
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Harris Corporation
Harris Semiconductor
P.O. Box 883
Melbourne, Florida 32901

19 October 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report summarizes the design effort on a photo detector assembly intended for use with a 6328-A optical input from a laser gdw system. The photodetector assembly shall consist of two chips: (1) photodiode chip and (2) preamplifier chip. The technology to be employed for fabrication of the chips is the D.I. linear technology.		

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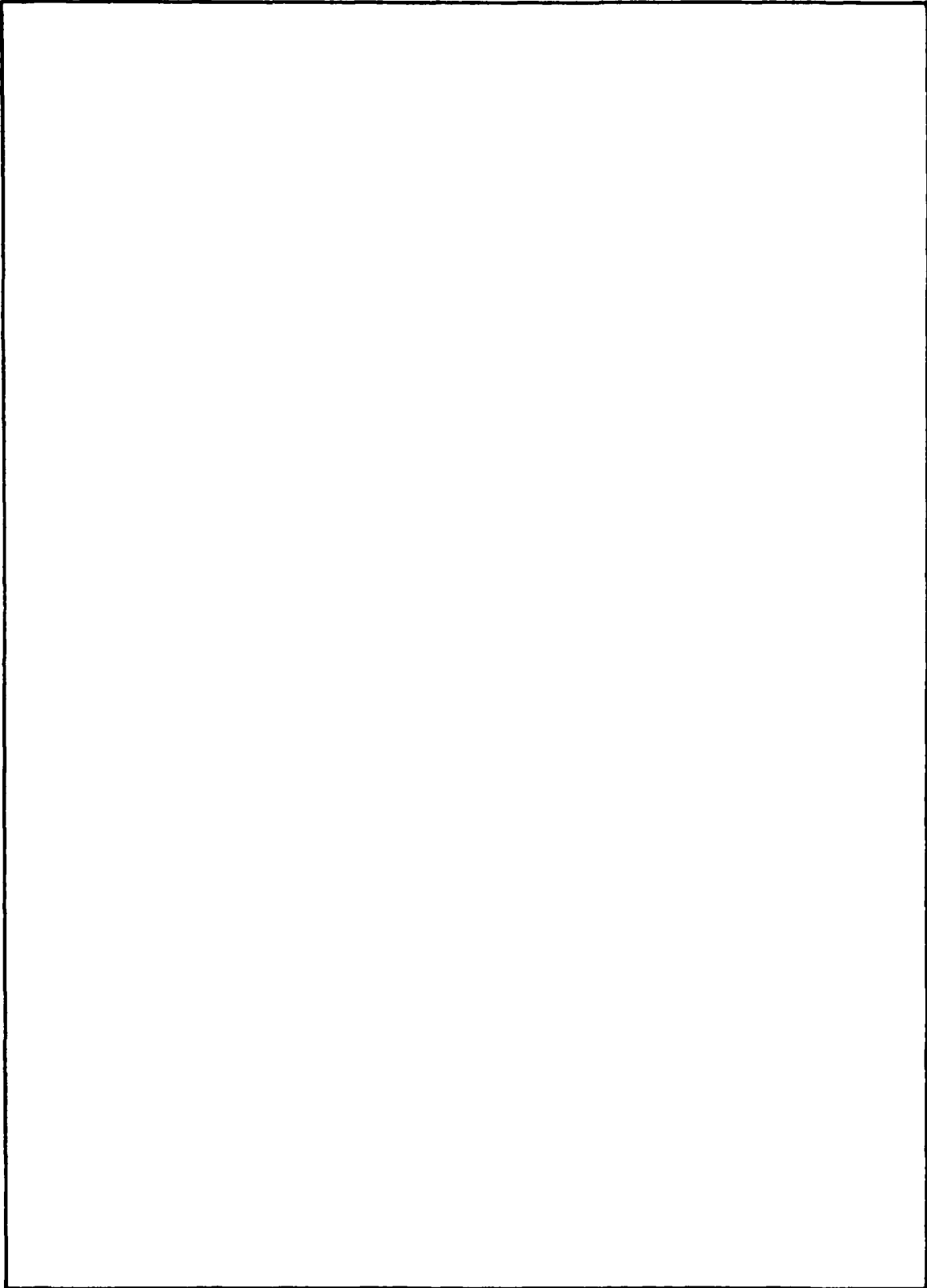
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1.0 INTRODUCTION AND SUMMARY

This report summarizes the design of a radiation-hardened photodetector circuit by the Harris Semiconductor Programs Division for the Defense Nuclear Agency's DINS Program (Contract DNA 001-78-C-0356). The DINS photodetector is a two channel detector/amplifier which detects ring laser gyro optical signals (6328Å). This is achieved by using three stages of signal conversion. The first stage is a photodiode which detects the incoming laser light signal and converts it to a small current. The second stage amplifies and converts this current to a small signal voltage. Finally, the third stage amplifies this small signal voltage to the output voltage level required.

Contained herein is a design description of the photodiode required for the photodetector. Reasons will be presented to explain the two die nature of the design. One die contains the input photodiodes plus large gain setting resistors while the second die contains the overall preamplifier circuit. Also following is the description of the preamplifier circuit which amplifies the output signal of the photodiode. Analyses of the proposed circuit have been performed by the SPICE II circuit simulation program which include DC, AC, Pre and Post radiation simulations over temperature and process variations.

The design effort is now complete and Harris is proceeding with the development of the DINS photodetector into topological design and prototype fabrication.

2.0 DESIGN REQUIREMENTS

The design requirements of the DINS photo detector system are enumerated as follows:

- The system shall receive a 300 nanowatt, (Min.) 6328⁰ signal from a ring laser gyro and convert it to a level in the hundreds of millivolts. It must do so in the presence of transient gamma radiation of the specification level and also after the exposure to neutron fluence of the specified level.
- The system shall have an adequate signal-to-noise ratio such that the input signal is not masked by the noise generated during a transient gamma event.
- Assuming the specified photodiode responsivity requirement of .44 Amps/Watt the preamplifier shall have a transimpedance gain of 3 megohms.
- The overall system bandwidth shall be a minimum of 1 megahertz.
- The preamplifier shall be capable of driving a capacitive load (i.e. coaxial cable).
- The preamplifier shall have short-circuit protection.
- A maximum of ± 20 volts of supply voltage may be used.
- The operating temperature range shall be -55°C to $+125^{\circ}\text{C}$.

3.0 TECHNICAL APPROACH

3.1 Shown in Figure 1 is the overall system functional diagram of the DINS photodetector. The system has been divided into two chips, a photodiode chip and an amplifier chip. The photodiode chip also contains four 30K ohm resistors which set the gain of the first stage of amplification. A total of eight chip to chip bond wires shall be required and five bond wires shall be brought out to the package. (Figure 2).

3.2 Circuit Partitioning

In order to obtain a 1 to 1 or better signal to noise ratio under minimum drive conditions (300 nanowatts), it is necessary to reduce the noise as much as possible without sacrificing photodiode responsivity. The main noise contributors in the system are the photocurrents produced by the photodiodes during a transient gamma event. Although these photocurrents are applied common mode to the preamplifier by using an identical masked photodiode to the non-inverting input, any mismatch in these currents will be applied as a differential signal and therefore show up in the output as the major noise contributor.

Transient I_{pp} (primary photocurrent) is a direct function of the photodiode's total volume since the generation rate $g_E(\gamma)$ is linear with the depth of the island. However, the input laser signal is exponentially attenuated by the absorption coefficient of the material. Therefore it is the photodiode's area which will directly influence its responsivity. Based on these facts it is evident that the photodiode should have a thin structure with sufficient area for the required responsivity. In this way any mismatch in photocurrents will be minimized by minimizing the total photocurrent.

An island thickness of 2.54 μm was chosen to maintain a small total volume. However this would be incompatible with bipolar transistor fabrication. Therefore the two die approach shown in Figure 1 was chosen. The four 30K ohm resistors were chosen to go on the photodiode chip since their fabrication would be more compact using a higher sheet resistivity than the 250 ohm/square of the amplifier chip. A sheet resistivity of 1000 ohm/square will be used for these resistors.

SYSTEM FUNCTIONAL DIAGRAM

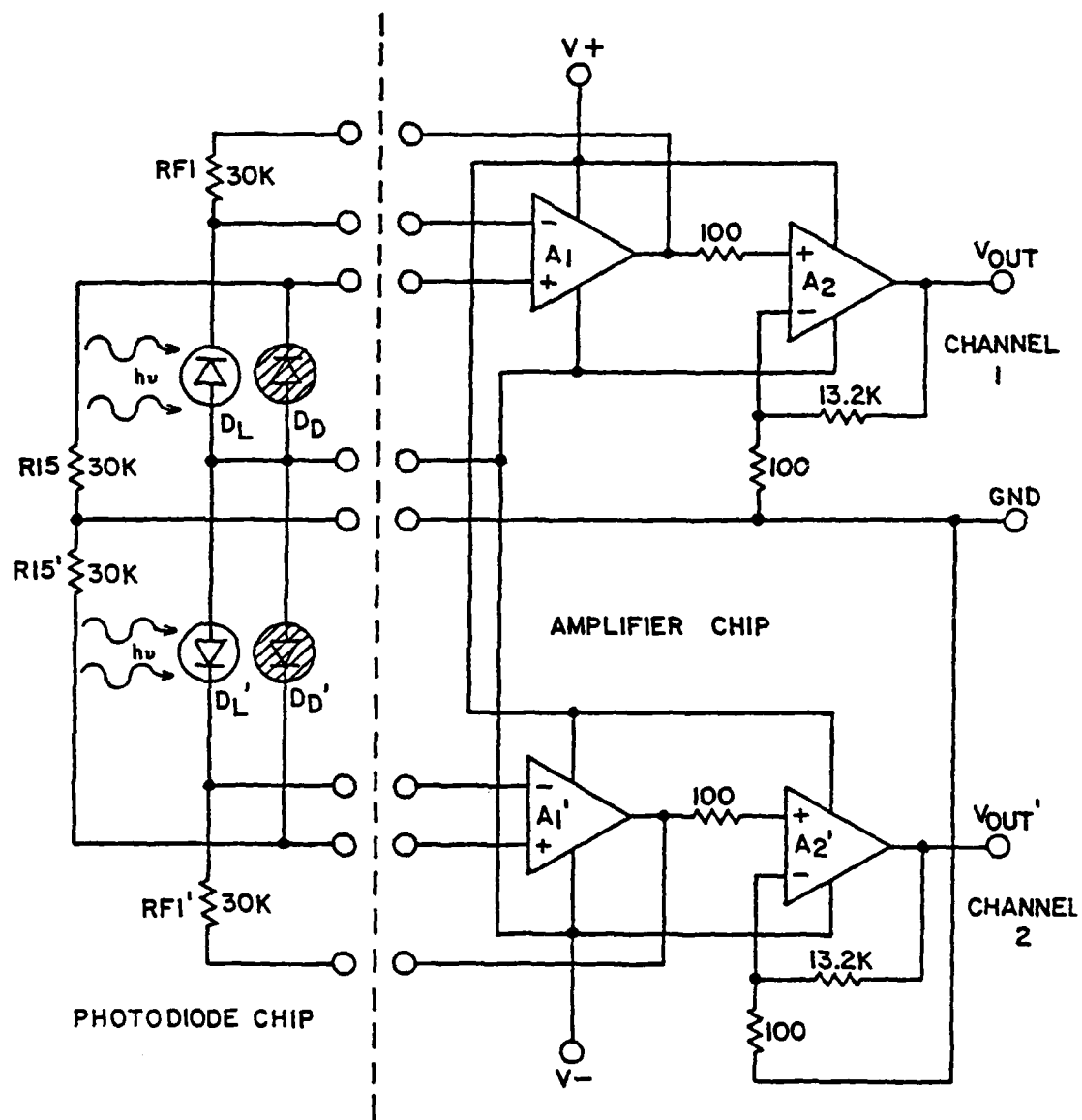


FIGURE 1

BONDING REQUIREMENTS

CHIP TO CHIP BOND WIRES

- Channel 1 Stage A, output to resistor $RF1$
 - Channel 2 Stage A', output to resistor $RF1'$
 - Channel 1 positive input to photodiode D_D and resistor $R15$
 - Channel 2 positive input to photodiode D_D' and resistor $R15'$
 - Channel 1 negative input to photodiode D_L and resistor $RF1$
 - Channel 2 negative input to photodiode D_L' and resistor $RF1'$
 - System ground
 - System negative power supply V^-
-

= 8 Total chip to chip bonds

CHIP TO PACKAGE BOND WIRES

No bond wires are required from the photodiode chip.

From the amplifier chip are required:

- System positive power supply V^+
 - System negative power supply V^-
 - Output of channel 1 V_{Out}
 - Output of channel 2 V'_{Out}
-

= 5 Total chip to package bonds

FIGURE 2

3.3 Gain Partitioning

In designing a radiation-hardened preamplifier with an overall gain-bandwidth product as large as the one required here, it is important that adequate consideration be given to the distribution of the overall preamplifier gain. The gain of the preamplifier is 3 megohms of transimpedance under worst case temperature and process variability conditions. This worst case criteria also applies to the specified 1 megahertz bandwidth parameter. Process variability for both resistors and capacitors is $\pm 10\%$. The worst case gain situation will occur at low temperature combined with both low resistors and capacitors. This implies (from simulations) that a nominal element, room temperature gain of 4 megohms will be necessary. Likewise for bandwidth, a nominal figure of 2 megahertz was chosen to guard against its worst case situation, which will occur at high temperature combined with both high resistors and capacitors.

Achieving a gain-bandwidth product of this magnitude is not feasible using only a single stage due to stability considerations. Therefore a two stage approach was chosen. Figure 3 shows the partitioning. The resistor names are those of the overall circuit. The value of transimpedance of stage A₁ (30K) and gain of stage A₂ (133) are values that require realistic gain-bandwidth products. Simulations show that under this configuration over 45° of phase margin can be obtained from each stage.

A second consideration is the amplifier's worst case input offset condition. The output level shift caused by this offset must still allow for the required maximum output voltage swing, which in this case is about half of a volt.

There are two types of offsets that can be generated at the inputs. Each stage has an inherent voltage offset due to V_{BE} mismatches in each respective input stage. This offset voltage appears at the output amplified by the voltage gain of the stage. In addition, beta degradation and mismatch post-neutron can cause currents (Figure 2) $I_{1(+)}$ and $I_{1(-)}$ to differ by as much as 20%. These currents which appear across the respective impedances seen at the input ports will generate an additional offset voltage which is

$$V_{os} = I_{1(+)} \cdot R_{15} - I_{1(-)} \cdot R_{F1}$$

The DC voltage gain of transimpedance A₁ is unity. Therefore, this offset voltage appears at the output multiplied by the voltage gain of A₂ which is 133. This same current induced voltage offset will occur at the input of A₂, however here the impedances seen by the input differential pair is only about 100 ohms so the voltage generated across them is small.

NPA betas may fall to 30 and PNP betas to 15 at the specified neutron level. Therefore:

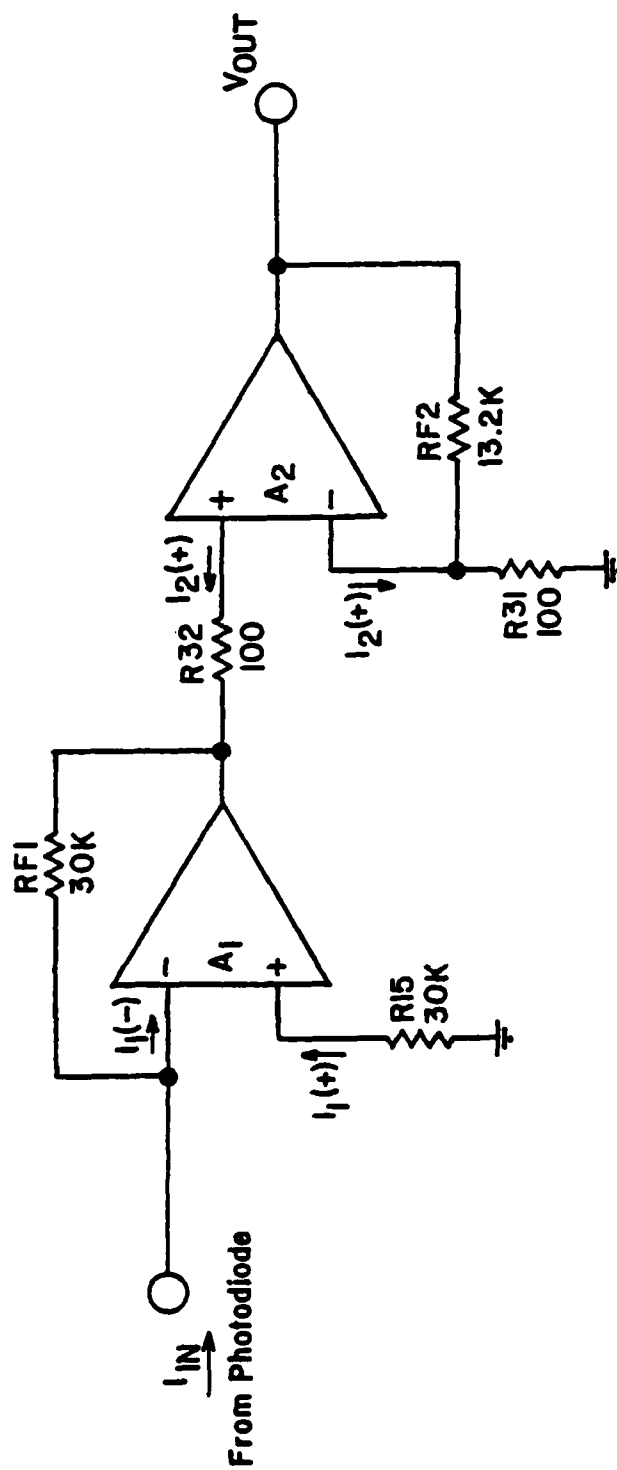
$$\Delta I_1 \cdot R_{F1} = .44 \mu A \times 30K = 13.2 \text{ mV (current induced offset)}$$

$$\Delta I_2 \cdot R_{31} = 2.4 \mu A \times 100 = .24 \text{ mV (current induced offset)}$$

$\Delta V_{IO_1} \leq$	10 mV	
$\Delta V_{IO_2} \leq$	10 mV	
	33.4 mV	Total V_{IO}

GAIN PARTITIONING

(ONE CHANNEL)



$A_1 = 30K$

$A_2 = 133$

OVERALL GAIN = 4 MEGOHMS

Figure 3

The total offset voltage multiplied by the voltage gain of the second stage brings the output voltage to 4.4 volts. Therefore a one half volt swing will not be a problem.

3.4 DIELECTRICALLY ISOLATED P+ - N⁻ - N+ PHOTODIODE

3.4.1 Theoretical Analysis of Silicon P+ -N⁻ -N+ Photodiode for 6328Å Laser Detection.

3.4.1.1 Theoretical Analysis of Quantum Yield and Photocurrent:

The theoretical analysis of the photo response for a silicon p+ -n⁻ - n+ photodiode based on the structure shown in Figure 3.4.1a is presented in this report. The photodiode structure consists of a p+ implanted layer of about 0.15μm thick, and n- layer of 40-μm and 2.5μm thick, and an n+ buried layer of about 2.5μm.

The spectral response of the photocurrent and quantum yield for this photodiode is analyzed as follows:

Figure 3.4.1b shows a schematic diagram of the p+ -n⁻ -n+ photodiode under reverse bias conditions. Let us consider a He-Ne laser (6328Å) impinging on the p+ surface at y = 0. The rate of generation of photocarriers is given by

$$g_E(y) = \phi_0 (1-R) e^{-\alpha y} \quad (1)$$

where ϕ is the incident photon flux density, R is the reflection coefficient of silicon.

Under steady state conditions, the total photocurrent density, J_{ph} , produced by the incident photons is the sum of the electron and the hole current components at any cross section of the photodiode, which can be expressed by:

$$J_{ph} = J_n(y_0) + J_p(y_0) = J_n(y_0) + J_p(y_1) + J_i \quad (2)$$

where

$$J_i = J_p(y_0) - J_p(y_1) \quad (3),$$

In Eq. (2), $J_n(y_0)$ denotes the electron current density at $y = y_0$, $J_p(y_1)$ is the hole current density evaluated at $y = y_1$ and J_i is the component of the hole current density arising from the carrier generation in the intrinsic region (i.e., n⁻ - region). To find the function dependence of the photocurrent and the quantum yield, we need to express $J_n(y_0)$, $J_p(y_1)$, and J_i as functions of ϕ_0 , α , $(y_1 - y_0)$, and y_0 . Detailed derivation of the photocurrent in each of these three regions (i.e., $0 \leq y \leq y_0$, $y_0 \leq y \leq y_1$, and $y_1 \leq y \leq y_2$) have been given by Li and Lindholm [1] for a silicon p-i-n photodiode, which is applicable to the present case. Thus, the photocurrent density for a photodiode shown in Figure 3.4.1b can be expressed by {1}:

$$J_{ph} = q\phi_0 (1-R) \left\{ -\frac{1}{\alpha L_n} \left[1 - \cosh \left(\frac{y_0}{L_n} \right) e^{-\alpha y_0} \right] \frac{1}{\sinh \left(\frac{y_0}{L_n} \right)} + \frac{e^{-\alpha y_1}}{1 + \alpha L_p} \right\} \quad (4)$$

and the quantum yield for the photodiode is given by:

$$\eta = \left| \frac{J_{ph}}{q\phi_0} \right| = (1-R) \left\{ \frac{1}{\alpha L_n \sinh \left(\frac{y_0}{L_n} \right)} \left[1 - \cosh \left(\frac{y_0}{L_n} \right) e^{-\alpha y_0} \right] - \frac{e^{-\alpha y_1}}{1 + \alpha L_p} \right\} \quad (5)$$

Equation (5) reduces to that of 'Gartner's expression' if y_0 and R are set equal to zero {2}.

Now we can apply equations (4) and (5) to compute the photocurrent and quantum yield in a $p^+ - n^- - n^+$ photodiode shown in Figure 1. The specifications for the photodiode studied in this report are given as follows:

Diode Area:	$A_j = 39.3 \text{ Mil}^2 = 2.456 \times 10^{-4} \text{ cm}^2$
Junction Depth:	$(p^+ - \text{Layer}) y_0 = 0.1 \mu\text{m} = 10^{-5} \text{ cm}$
Dopant Density:	$n^- - \text{Layer} \rightarrow N_D = 10^{15} \text{ cm}^{-3}, \rho = 4 \Omega\text{cm}$
Thickness:	$n^- - \text{Layer} \rightarrow y_1 - y_0 = 2.5 \mu\text{m} = 2.5 \times 10^{-4} \text{ cm}$
Buried Layer ($n^+ - \text{Layer}$) Thickness:	$y_2 - y_1 = 2.5 \mu\text{m} = 2.5 \times 10^{-4} \text{ cm}$
Incident Photon Power Density:	$P_{in} = 300 \text{ nW}, \phi_0 = 3.89 \times 10^{15} \text{ Photons/cm}^2$
Incident Photon	$\lambda_0 = 6328 \text{ \AA} = 0.6328 \mu\text{m}$
Absorption Coefficient:	at λ_0 in Si $\Rightarrow \alpha = 3.5 \times 10^3 \text{ cm}^{-1}$
Hole Diffusion Length in n^- - Region:	$L_p \cong 0.01 \text{ cm}$
Electron Diffu- sion Length In $p^+ - \text{Region}$:	$L_n \cong 10^{-3} \text{ cm}$

Substituting the above listed numerical values for different parameters in Eqs. (4) and (5) yields:

$$J_{ph} = 0.543 \text{mA/cm}^2, \text{ and } \eta = 0.873$$

$$I_{ph} = 1.33 \times 10^{-7} \text{A for } P_{in} = 300 \text{nW}$$

The above results are obtained by assuming that the reflection loss is negligible at the surface of the photodiode.

Table 1 summarizes the calculated values of photocurrent, quantum yield and responsivity (assuming $R = 0$) of a silicon $p^+ - n^- - n^+$ photodiode for different junction depths (i.e., different thicknesses of the p^+ layer) with $P_{in} = 300 \text{nW}$.

Table 1. - Theoretical calculations of the photocurrent, quantum yield, and the responsivity of a silicon $p^+ - n^- - n^+$ photodiode for different junction depths (y_0). The incident laser beam (6328Å) intensity is assumed equal to 300nW.

Junction Depth (y_0) μm	Photocurrent I_{ph} (nA)	Quantum Yield (η)	Responsivity (A/W)
0.10	133	0.873	0.44
0.15	132	0.865	0.44
0.20	131	0.856	0.437
0.25	130	0.848	0.433
0.30	128	0.84	0.426
0.40	126	0.825	0.42
0.50	124	0.809	0.413

It is noted that the above calculations are based on the assumptions that the reflection loss is negligible and the dopant densities in both $p^+ -$ and n^- - layer are fixed. A change in the dopant density in both $p^+ -$ and n^- - layer would in general change the quantum yield as well as responsivity of the photodiode.

3.4.1.2 ANTIREFLECTION (AR) COATINGS

In order to reduce the reflection loss at the silicon photodiode surface, it is important to incorporate the AR coatings in the design of photodiode. Theoretical considerations for the AR coatings in a silicon $p^+ - n^- - n^+$ photodiode are described as follows:

1.0. Single Layer AR Coating

To achieve a minimum reflection loss, a single layer dielectric film can be coated on top of the photodiode. Dielectric films commonly used in AR coatings include SiO_2 , SiO , Al_2O_3 , TiO_2 , Ta_2O_5 , and Si_3N_4 . To obtain minimum reflection loss, the thickness of the dielectric film can be chosen to be equal to quarter wavelength of the incident photon. For examples, if SiO_2 film is chosen, then

with $n_1 = 1.5$ for SiO_2 and $\lambda_0 = 6328\text{\AA}$, $d_1 = \frac{\lambda_0}{4n_1} = \frac{6328\text{\AA}}{4 \times 1.5} = 1055\text{\AA}$

If Si_3N_4 is chosen, then with $n_1 = 2.0$, $d_1 = \frac{6328\text{\AA}}{4 \times 2} = 781\text{\AA}$

The reflection loss can be calculated from

$$R_{\min} = \left[\frac{(n_1^2 - n_0 n_2)}{(n_1^2 + n_0 n_2)} \right]^2 \quad (6)$$

Where n_1 is the index of refraction of the dielectric film, n_0 is the index of refraction of air and n_2 is for silicon.

For the case of SiO_2 - Si system the reflection loss is only about 7% when 1100\AA SiO_2 is deposited on silicon photodiode. For Si_3N_4 - Si case reflection loss is only 0.016% if 800\AA Si_3N_4 AR coating is used!

The above theoretical calculations show clearly that the reflection loss in a silicon photodiode can be reduced to near zero by simply employing a single layer of dielectric film (i.e., SiO_2 , or Si_3N_4) as AR coating on the silicon photodiode.

2.0. Double Layer AR Coating

In addition to the single layer AR coating, one can also use double layer AR coating. In this case, two different types of dielectric film each with a quarter wavelength thick can be applied to the photodiode surface as AR coating. The minimum reflection loss can be calculated by using the expression:

$$R_{\min} = \left(\frac{n_1^2 n_3 - n_2^2 n_0}{n_1^2 n_3 + n_2^2 n_0} \right)^2 \quad (7)$$

Where n_0 is the index of refraction of air, n_1 is the index of refraction for the first AR coating layer and n_2 is for the second coating layer, and n_3 is the index of refraction for the silicon substrate.

If the thickness of SiO_2 and Si_3N_4 AR coatings were chosen to be $\frac{1}{4}$ wavelength of incident Radiation, then the thicknesses of these two layers are given respectively by $d_1 = 1055\text{\AA}$ (for SiO_2) and $d_2 = 790\text{\AA}$ (for Si_3N_4), and the reflection loss calculated from Eq. (7) is 0.14 which is considerably higher than the single layer AR coatings calculated earlier.

Table .2. Summarizes the calculations of AR coatings for the silicon p+ - n⁻ - p+ photodiode reported here.

Dielectric Film	Thickness a (\AA)	Minimum Reflection Loss R_m (at 6328\AA)	Refractive Index
SiO_2	1055	7%	1.5
Si_3N_4	781	0.016%	2.0
Ta_2O_5	703	0.3%	2.25
$\text{SiO}_2/\text{Si}_3\text{N}_4$	1055/781	14%	1.5/2.0

Table 2 - Single layer and double layer AR coatings for silicon $p^+ - n^- - n^+$ photodiode.

3.4.1.3 SUMMARY

In this report, we have shown theoretically that a responsivity of around 0.45 A/W can be achieved by using the proposed geometry and structure in the $p^+ - n^- - n^+$ silicon photodiode. The reflection loss can be minimized to a negligible level if a single layer dielectric film such as SiO_2 or Si_3N_4 with thickness equal to the quarter wavelength of the laser radiation is used as AR coating for the photodiode.

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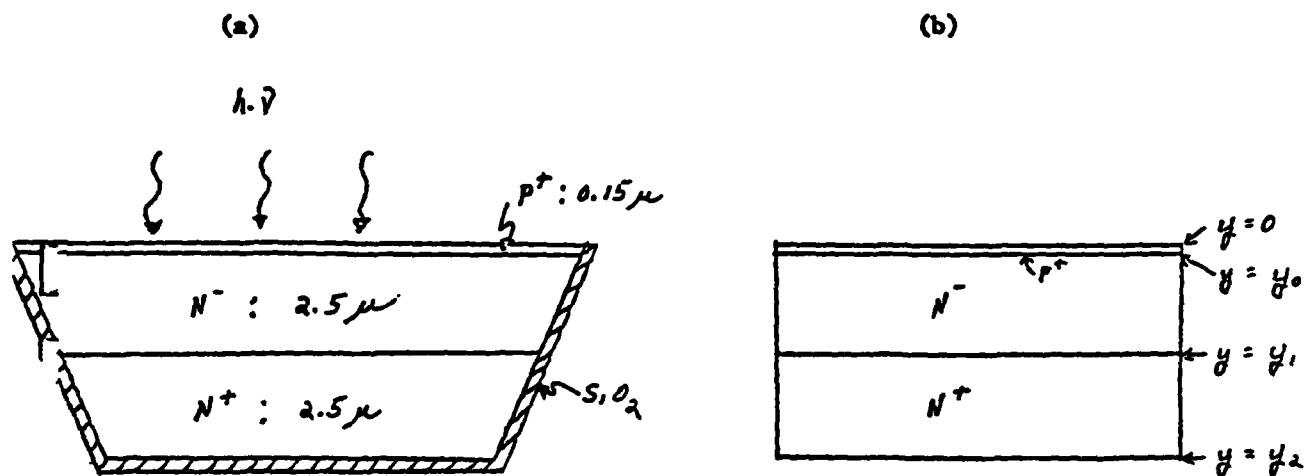


FIGURE 3.4.1. A SILICON $p^+ - n^- - n^+$ PHOTODIODE

(i) Reverse Leakage Current (I_R):

The reverse leakage current in the $p^+ - n^- - n^+$ photodiode can be calculated from

$$I_R = \frac{q n_i W_D A_j}{2t_i} \quad (1A)$$

Where n_i is the intrinsic carrier density, W_D is the depletion layer width, A_j is the junction area, and t_i is the carrier lifetime.

For large reverse bias ($V_j \leq -4.2V$), the depletion layer width is given by

$$W_D = W_N = 2.5 \mu m$$

If $t_i \geq 100 \text{ ns} = 10^{-7} \text{ s}$, then

$$I_R = \frac{1.6 \times 10^{-19} \times 1.4 \times 10^{10} \times 2.5 \times 10^{-4} \times 2.456 \times 10^{-4}}{2 \times 10^{-7}}$$

$$= 6.877 \times 10^{-10} \text{ A} \quad \text{at } 300K$$

(ii) Junction Capacitance of the $p^+ - n^- - n^+$ Photodiode

The junction capacitance for the $p^+ - n^- - n^+$ photodiode can be calculated from

$$C = \frac{A_j C_{j0}}{\left(1 - \frac{V_j}{\phi_b}\right)^{\frac{1}{2}}} \quad (E1)$$

where

$$A_j = 2.456 \times 10^{-4} \text{ cm}^2$$

$$\phi_B = \left(\frac{2kT}{q}\right) \ln \left(\frac{N}{n_i}\right) = 0.5756V$$

$$C_{j0} = \left(\frac{q \epsilon_s N}{2\phi_B}\right)^{\frac{1}{2}} = 1.2 \times 10^{-8} \text{ F/cm}^2$$

$$C_j = \frac{3.1}{(1 - 1.75 V_j)^{\frac{1}{2}}} \text{ PF} \quad (E2)$$

where V_j is the bias voltage.

For example :

at $V_j = -10V$, $C_j = 0.72pF$.

The capacitance due to SiO_2 isolation around the photodiode can be estimated by

$$C_I \approx \frac{A_I \epsilon_{OX}}{t_{OX}} \quad (B3)$$

where $\epsilon_{OX} = 4$, $A_I = 2.775 \times 10^{-4} \text{ cm}^2$, $t_{OX} = 1.8\mu m$

$$C_I = 0.546pF$$

(iii.) Gamma Radiation Current (I_{pp})

The gamma radiation current can be calculated from the following expression:

$$I_{pp} \approx qg_o A_j (W_p + L) \dot{\gamma} \quad (C1)$$

where $g_o = 4 \times 10^{13} / \text{Rad}$

For the $p^+ - n^- - n^+$ photodiode considered, $W_p = W_n = 2.5\mu m$, the effective diffusion length in the buried layer is essentially the thickness of this layer (W_{BL}), thus

$$L \approx W_{BL} = 2.5\mu m$$

and

$$I_{pp} / \dot{\gamma} = 0.81 \text{ PA/rad/S}$$

If $\dot{\gamma} = 10^7 \text{ Rads/S}$ then

$$I_{pp} = 8.1\mu A$$

A test chip was designed with various geometry photodiodes to determine an optimum performance design compatible with existing process capabilities. Three pairs of diodes were designed on the test chip; a pair consisting of an open diode for detecting a 6328Å He-Ne laser and an identical geometry dark diode, masked from the laser with aluminum, for radiation photocurrent compensation. This section describes the three designs and the advantages and disadvantages of each.

Photodiode Design #1: Stepped D.I.

Figure 3.4.2 shows the stepped D.I. design. The dielectric isolation pattern of this design was stepped, anticipating that the natural corner rounding which occurs during the anisotropic silicon etch (moat etch) would result in a circular shaped island. However the etch time required to etch the shallow island (0.2 - 0.3 mil) resulted in only minimal corner rounding. As a result, the final island geometry closely replicates the drawn island geometry as shown in the design.

The anode is a 5.0 mil radius semicircle with 0.2 mil spacing between the anode aperture and the minimum D.I. island. P^+ contact to the anode is made via a 0.6 by 9.0 mil aperture along the diameter of the semicircle. The N^+ contact to the cathode is a 0.6 by 0.6 mil aperture spaced 0.3 mil from the anode aperture.

Photodiode Design #2: Stepped D.I. with N^+ Ring

The stepped D.I. with N^+ ring design is shown in Figure 3.4.3. Additional steps were added in the dielectric isolation pattern to determine if the corner rounding effect with the additional steps would result in a more uniform semicircular pattern. However as in the previous design the minimal required etch time resulted in the final island geometry being very similar to the design island geometry.

The anode of this design is identical to the previous design.

A 0.4 mil N^+ ring spaced 0.3 mil from the anode was designed for the cathode contact. This ring provides a lower resistance cathode contact to enhance the efficiency of the diode. The disadvantage of this design is that the addition of the N^+ ring increases the total island volume over the previous design which could result in an increase in radiation induced photocurrent. The trade-off to be evaluated then is improved photodiode performance vs. radiation hardness.

Photodiode Design #3: Circular D. I. Island

The circular D.I. island design is shown in Figure 3.4.4. This design was included to study the feasibility of anisotropically etching a circular pattern at the dielectric isolation photoresist and moat etch process steps.

No significant problems were encountered on the first run at the D.I. photoresist and moat etch steps. In fact the final island geometry was very close to the designed geometry.

The anode, anode contact and cathode contact were identical to Design #1.

PHOTODIODE DESIGN # 1

STEPPED D.I.

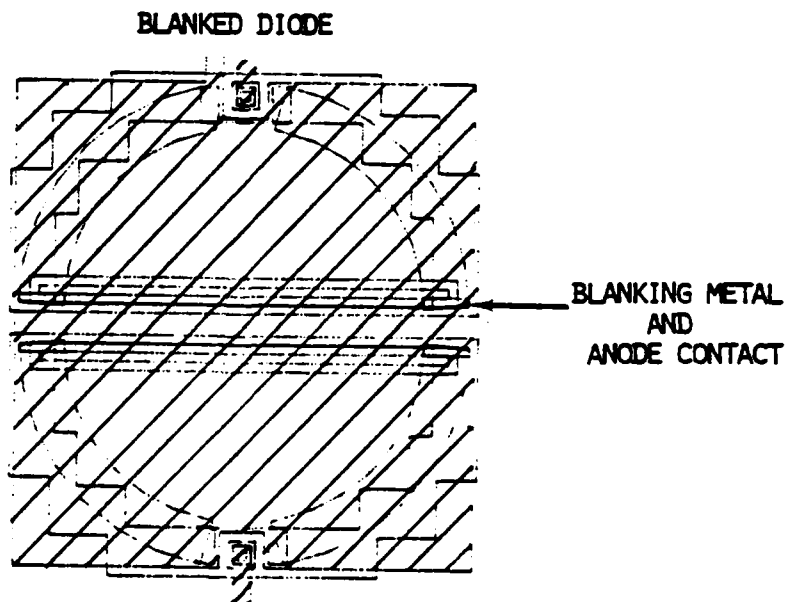
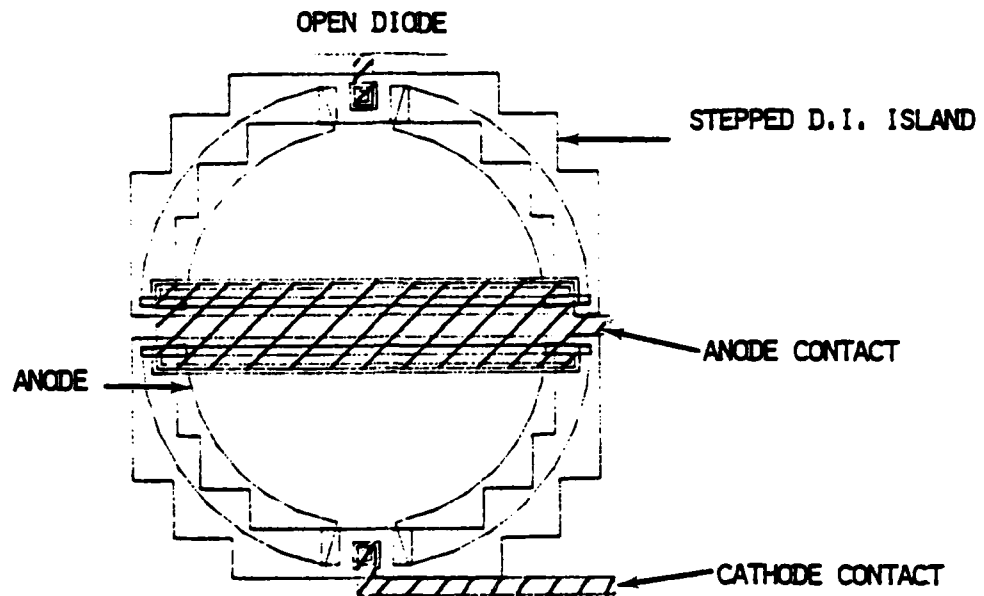


Figure 3.4.2

PHOTODIODE DESIGN #2 STEPPED D.I. & N⁺ RING

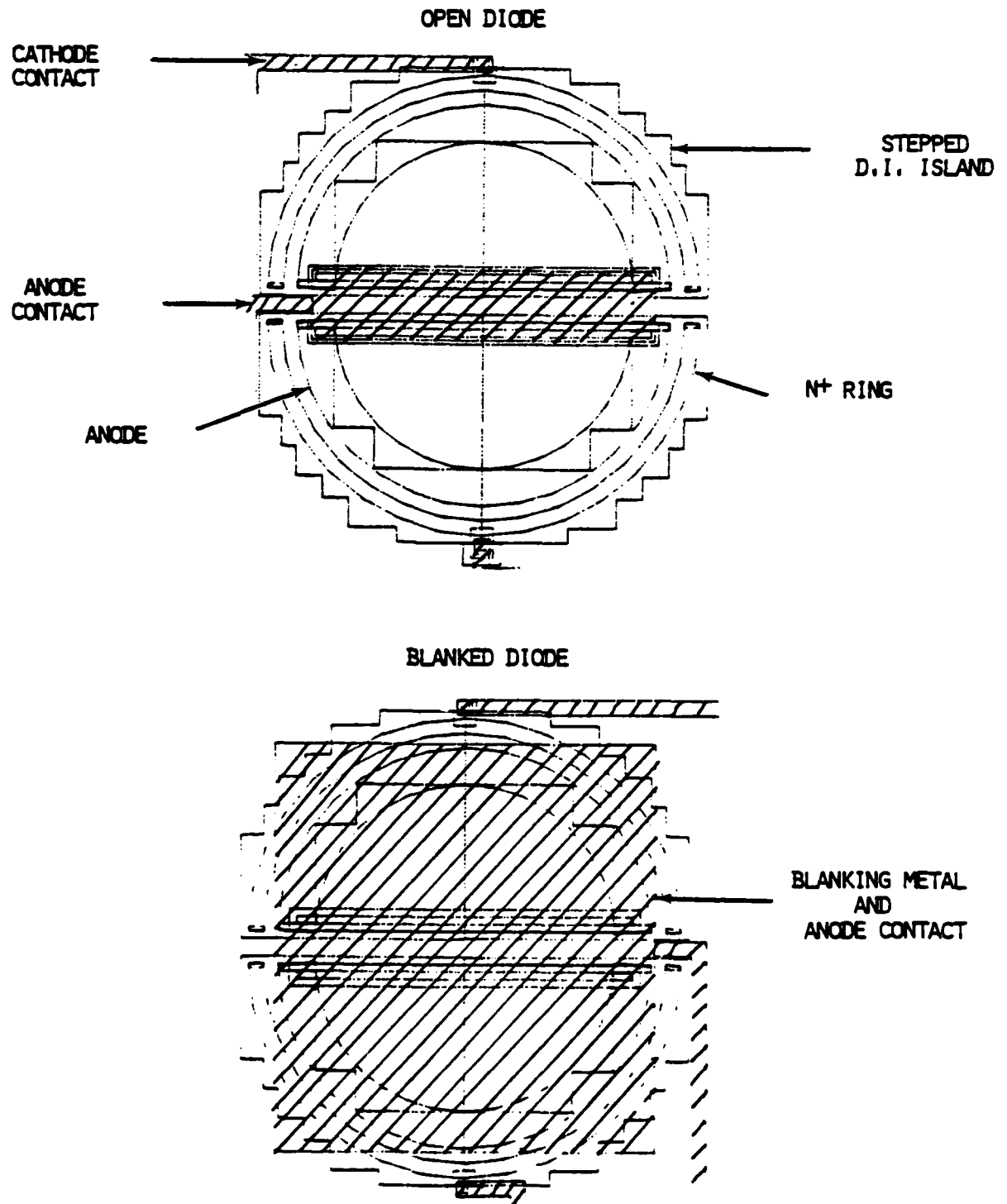


Figure 3.4.3

PHOTODIODE DESIGN #3
CIRCULAR D.I. ISLAND

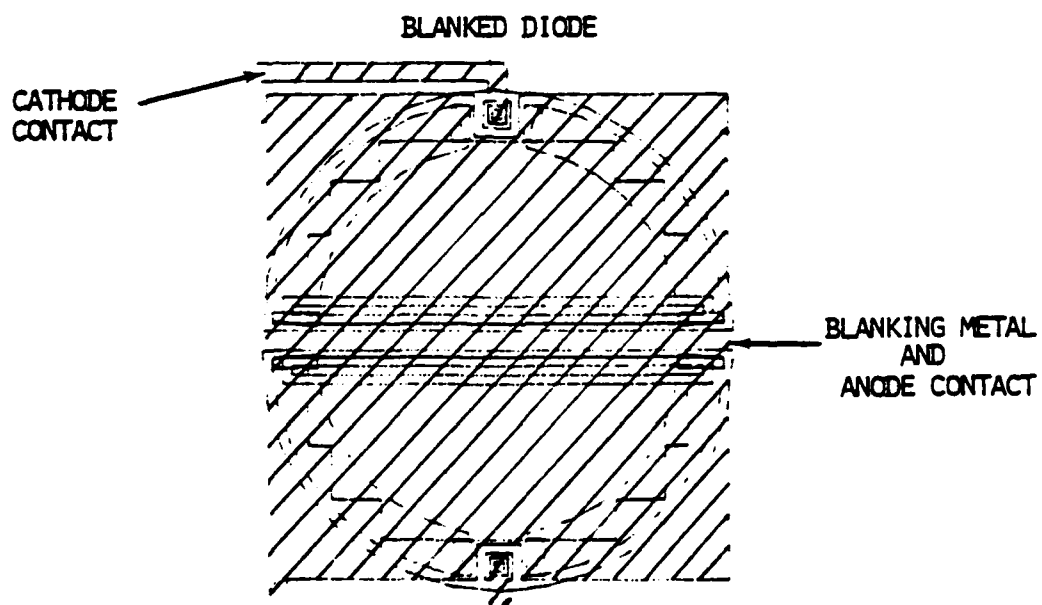
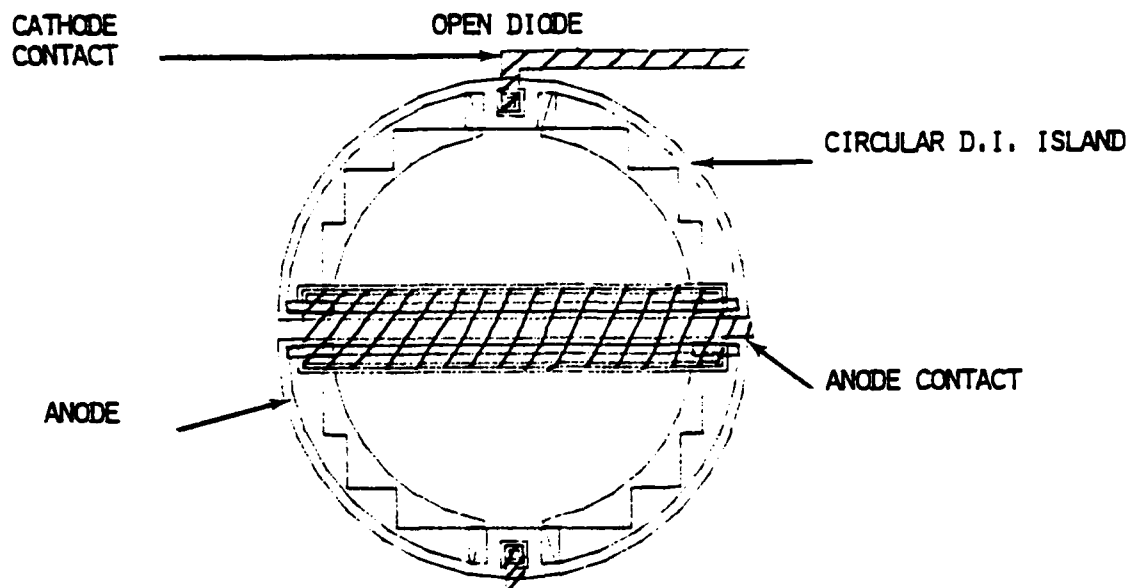


Figure 3.4.4

3.4.3 Process Description

This section describes the process employed to fabricate the photodiodes. Both the dielectric isolated materials process and the frontside wafer fabrication process will be described as well as the process permutations employed on the first run of photodiodes.

3.4.3.1 Materials Fabrication Process

1.0 Starting Substrate:

Resistivity: 3-5 ohm-cm N-type

Orientation: <1-0-0>

Background Concentration: $\sim 10^{15} \text{ cm}^{-3}$

Diameter: 3 - inch

2.0 Buried Layer Formation:

After the buried layer pattern is defined in the field oxide, the buried layer is formed via a two step ion implantation and diffusion operation. The final buried layer process parameters are:

$$\rho_s \cong 25 \text{ ohms/sq.}$$

$$x_j = 2.5 \mu$$

$$C_s \cong 4 \times 10^{19} \text{ cm}^{-3}$$

3.0 Dielectric Formation:

The dielectric isolation is delineated in the field oxide followed by an anisotropic silicon etch to form the isolation moats. The precise geometry of the moats is defined by the isolation photoresist pattern and the fact that the etch proceeds down the <1-1-1> plane. Following the moat etch, the dielectric oxide is thermally grown.

$$t_{ox} = 1.0 \mu$$

4.0 Polycrystalline Silicon Deposition:

The polycrystalline silicon is chemically vapor deposited to achieve the final substrate thickness of ~ 25 mils.

5.0 Final Polish:

The wafers are then chemically-mechanically polished to the specified isolated island thickness of 5 - 7.5 microns.

3.4.3.2 Wafer Fabrication Process

1.0 Initial Oxidation:

The first step in the wafer fabrication process is a thermal oxidation to grow the field oxide followed by a crystal anneal to anneal out the mechanical polish damage.

$$t_{ox} = 0.4 \mu$$

2.0 N⁺ Cathode Contact:

Following a photoresist operation to delineate diffusion apertures to the n⁻ cathode, the n⁺ cathode contact is formed by a two step phosphorus predeposition and diffusion operation. This process results in the following parameters:

$$\rho_s = 10 \text{ ohms/sq.}$$

$$x_j = 2.5 \mu$$

$$C_s = 3.0 \times 10^{20} \text{ cm}^{-3}$$

3.0 P⁺ Anode Contact:

After the P⁺ aperture pattern is etched in the field oxide, the P⁺ anode contacts are formed with a two step boron predeposition and diffusion process. The resulting parameters are:

$$\rho_s = 125 \text{ ohms/sq.}$$

$$x_j = 0.6 \mu$$

$$C_s = 4.0 \times 10^{19} \text{ cm}^{-3}$$

4.0 Anode Formation:

A 5 mil radius circular pattern is etched in the field oxide for the anode of the photodiode. Subsequent to the etching operation, 1100Å of thermal oxide is grown in the opened anode area. This oxide serves to control the peak of the anode ion implantation. Boron is then ion-implanted to form the p⁺ anode. The following are the ion implantation parameters:

$$\text{Energy} = 100 \text{ KeV}$$

$$\text{Dose} = 2.3 \times 10^{-3} \text{ coul.}$$

$$\text{Projected Range} = 0.12 \mu$$

$$\text{Peak Concentration} = 2.5 \times 10^{19} \text{ cm}^{-3}$$

5.0 Antireflection Coating and Si₃N₄ Passivation:

If a silicon nitride AR coating is desired, then the 1100Å of thermal oxide is removed from the anode area and 800Å of silicon nitride is chemically vapor deposited over the wafer. If an SiO₂ AR coating is preferred, then the 1100Å of thermal oxide is left over the anode and the 800Å of silicon nitride is later etched from the anode area, exposing the 1100Å SiO₂ AR coating.

6.0 Contact Apertures:

The contact aperture pattern is plasma etched in the silicon nitride and the underlying thermal oxide is dipped out creating the anode and cathode contact apertures.

7.0 Interconnect Formation:

A 1,2 μ thick aluminum/2% silicon film is sputtered over the wafer and the interconnect pattern is then delineated in this film.

8.0 Passivation and Backlap:

An 8000 \AA film of SiO_2 is chemically vapor deposited over the wafer to serve as a passivation layer.² The bond pad pattern and the anode of the photodiode is etched in the passivation oxide. The wafers are then thinned to the final die thickness of 11 mils.

3.4.3.3 Vertical Cross-Section

Figure 3.4.5 depicts the vertical cross-section of the dielectrically isolated photodiode.

3.4.3.4 Process Permutations

To establish an optimum process for the photodiode fabrication, several process permutations were employed on the 1st run.

3.4.1.0 Buried Layer vs. No Buried Layer:

Wafers 1 - 10: Buried Layer

Wafers 11 - 20: No Buried Layer

3.4.2.0 Antireflection Coating:

Even numbered wafers: Silicon nitride AR

Odd numbered wafers: Silicon Dioxide AR

3.4.3.0 Crystal Anneal:

Anneal #1: Wafers 6-10 and 16-20

Ramped initial oxidation and anneal

Anneal #2: Wafers 1, 2, 11 and 12

Harris standard initial oxidation and anneal

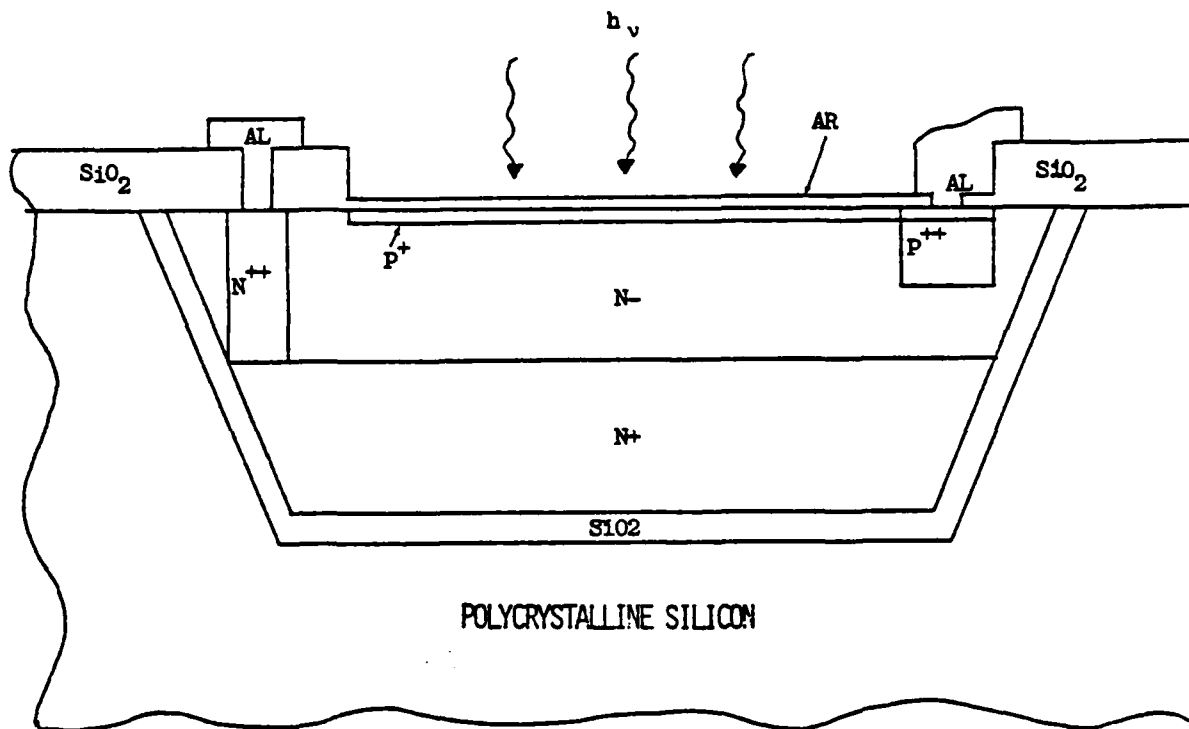
Anneal #3: Wafers 3, 4, 5 and 13, 14 and 15

Harris standard initial oxidation with no anneal

3.4.4.0 Preliminary Results

The responsivity and dark currents with and without radiation and the photocurrent generation constant of the various process permutations were evaluated by Honeywell personnel. This section summarizes the results of those evaluations.

IDEALIZED VERTICAL STRUCTURE OF PHOTODIODE



N⁺ Buried Layer

$$C_s \approx 1.0 \times 10^{19} \text{ cm}^{-3}$$

$$N^+ \text{ thickness} = 2.5\mu$$

N⁻ Layer

$$C_B \approx 1.0 \times 10^{15} \text{ cm}^{-3}$$

$$N^- \text{ Thickness} = 2.5\mu$$

P⁺ Anode

$$C(\text{Peak}) \approx 2.5 \times 10^{19} \text{ cm}^{-3}$$

$$\overline{R}_p = 0.12\mu$$

P⁺⁺ Anode Contact

$$C_s \approx 4.0 \times 10^{19} \text{ cm}^{-3}$$

$$P^{++} \text{ Penetration} = 0.6\mu$$

N⁺⁺ Cathode Contact

$$C_s \approx 3.0 \times 10^{20} \text{ cm}^{-3}$$

$$N^{++} \text{ Penetration} \approx 2.5\mu$$

Figure 3.4.5

3.4.4.1 Responsivity

Table 3.4.1 summarizes the average responsivity results for the various processes for the circular design and the N⁺ cathode ring design before and after exposure to gamma radiation. The responsivity was calculated as follows:

$$R = \frac{\text{Amp}}{\text{Watt}} = \frac{\text{current out} - \text{dark current}}{\text{Watts}(6328\text{\AA}) \text{ in}}$$

where the input power of the He Ne laser was approximately one μ watt. From this data it appears that the N⁺ ring design with a silicon nitride AR coating (wafer #8) is optimum. Comparing wafer #8 (Si₃N₄ AR with buried layer) with wafer #18 (Si₃N₄ AR without buried layer) it appears that the presence of the buried layer has little effect on responsivity. The most notable processing effect on responsivity is the AR coating, with the Si₃N₄ AR coating (even numbered wafers) resulting in a higher responsivity than the SiO₂ AR coating.

3.4.4.2 Differential Responsivity

Differential responsivity is defined as the responsivity difference between the unmasked and masked photodiodes. Table 3.4.2 summarizes the results of these measurements. Again the results show that the N⁺ ring design and the wafer #8 process is optimum.

3.4.4.3 Dark Current

The dark is the reverse bias leakage current measured at -10V on the anode. Table 3.4.3 summarizes the results of the dark current measurements. All diodes displayed less than 10 nA dark current.

3.4.4.4 Photocurrent Generation constant

Table 3.4.4 summarizes the empirical results of the photocurrent generation constants for the two designs and the various process permutations.

3.4.4.5 Photocurrent Balance

In general, the photocurrent balance between the masked and unmasked diodes was poor - greater than 10% in some instances. It was also found that the balance was sensitive to total ionizing dose. Modifications to the design and further characterization of the material and process have been initiated in an attempt to improve the balance.

Average Responsivity In Amps Per Watt of Diode
With and Without Gamma Radiation From Columns A + B

Wafer #	Gamma Radiation Circular	No Radiation Circular	Gamma Radiation N + Ring	No Radiation N + Ring
1	---	.238	---	.310
8	.382	.261	.439	.312 *
11	.264	.205	.303	.249
15	.294	.264	.357	.344
17	.268	.294	.273	.284
18	.321	.375	.419	.426

* The diodes in package 7 appear to be marginally functional. Excluding their data this number would be 463.

TABLE 3.4.1

**Average Responsivity Per Wafer In
Amps Per Watt From Columns E & F**

<u>Wafer #</u>	<u>Circular Diode</u>	<u>N + Ring Diode</u>
1	.235	.343
8	.338	.440
11	.236	.258
15	.271	.318
17	.267	.261
18	.392	.403

TABLE 3.4.2

Average Dark Currents In 10^{-10} Amps of Diodes With
and Without Gamma Radiation

Wafer #	Gamma Radiation Circular	No Radiation Circular	Gamma Radiation N + Ring	No Radiation N + Ring
1	---	97	-----	40
8	17	33*	94**	8
11	11	5	9	0
15	7	7	5	4
17	62	1	16	56***
18	75	6	13	8

- * Without package 8 diode 4 this number would be 4.
- ** Without package 5 diode 3 this number would be 9.
- *** Without package 24 diode 1 this number would be 7.

TABLE 3.4.3

PHOTOCURRENT GENERATION CONSTANT

WAFER #	GENERATION CONSTANT ($\times 10^{13}$ COUL/RAD)	
	N ⁺ RING DESIGN	CIRCULAR DESIGN
1	5	6.9
8	5.2	5.3
11	5.5	6.3
15	10	9.5
17	4.1	4.8
18	7.2	8.0

TABLE 3.4.4

3.5 PROCESS DESCRIPTION: PHOTODIODE PREAMP

The preamp uses a standard Harris linear process featuring dielectric isolation, complementary NPN/PNP devices, MOS capacitors and implanted high sheet resistors. The process description will be divided into a material fabrication section and a frontside processing section. Material fabrication covers the sequence from starting material to slice grind and polish, frontside processing covers initial oxidation through backlap.

1. MATERIAL FABRICATION. This sequence is outlined below.

Initial Oxidation
P Collector Photoresist and Etch
P Collector Diffusion
N+ Buried Layer Photoresist and Etch
N+ Buried Layer Diffusion
Isolation Photoresist and Etch
Anisotropic Moat Etch
Isolation Oxidation
Polycrystalline Si Deposition
Front Side Lap and Polish

- Initial oxidation grows a masking oxide on the polished slice. Starting resistivity is 3-6 ohm-cm; orientation is 1-0-0; slide diameter is 3"; and slice thickness is 20 mils.
- P collector photoresist/etch defines collector areas for PNP devices.
- P collector diffusion establishes a deep, lightly doped boron diffusion for use as a PNP collector. (Figure 1).
- N+ buried layer PR and diffusion establishes a heavily As doped layer used as a low resistivity subcollector for the NPN devices. (Figure 2).
- Isolation photoresist defines the isolation grooves.
- Isolation etch is anisotropic; the etch will stop on the 1-1-1 plane and hence the groove depth is defined by its width. (Figure 3).
- Isolation oxidation is performed next; oxide thickness is 1.8 μ nominal for defect density reduction. See Figure 4.
- Polycrystalline silicon is then deposited to a thickness of approx. 25 mils. This poly forms the substrate of the dual slice. (Figure 4).
- The original single-crystal slice is then ground away and the resulting structure is polished. The result is a largely polycrystalline slice with isolated regions of single-crystal Si. Note that both P and N type regions are available and that the N region also was an N+ buried layer. The slice has completed material fabrication at this point. Figure 5 illustrates the finished structure.

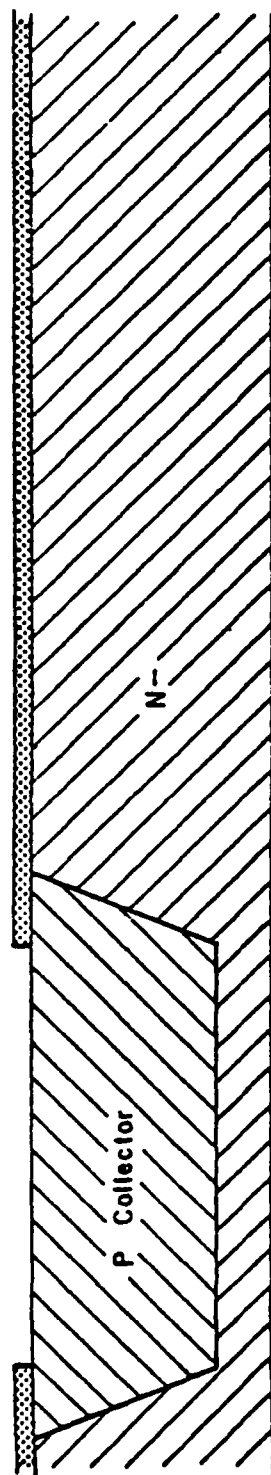
2. FRONTSIDE PROCESSING. Sequence is given below.

High Temperature Crystal Anneal
N-Base Photoresist and Oxide Etch
N-Base Diffusion
P-Base Photoresist and Oxide Etch
P-Base Diffusion
P-Emitter Photoresist and Oxide Etch
P-Emitter Diffusion - PNP Transistor Beta Piloted
N-Emitter Photoresist and Oxide Etch
N-Emitter Diffusion - NPN Transistor Beta Piloted
Capacitor Photoresist and Oxide Etch
Capacitor Low Temperature Oxidation
Implanted Resistor Photoresist and Oxide Etch
Resistor Low Temperature Oxidation
Resistor Implantation
Contact Photoresist and Oxide Etch
Sample Probe
Aluminum Evaporation
Aluminum Photoresist and Metal Etch
SiO₂ Deposition
Contact Base
SiO₂ Photoresist and Oxide Etch
Stabilization Base
Sample Probe
Backlap

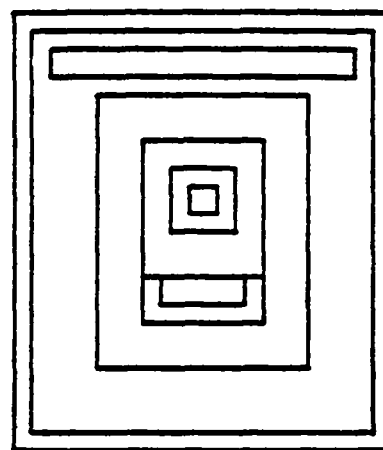
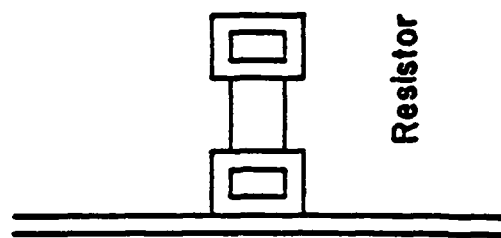
- A high temperature crystal anneal follows the 1100° initial oxidation; it stabilizes the structure and reduces defects.
- N base PR and diffusion establishes the PNP base. (Fig. 6).
- P base PR and diffusion establishes the NPN base. (Fig. 7).
- P+ PR and diffusion completes the PNP device; a piloting procedure controls device beta. Contact regions for the NPN base and PNP collector are also formed at this step. (Fig. 3).
- N + PR and diffusion completes the NPN device; again, piloting controls NPN beta. PNP base and NPN collector contact regions are also formed. (Fig. 9).
- Capacitor photoresist opens the capacitor dielectric area located over a P + diffusion used for the lower capacitor plate. A low temperature oxidation is then used to grow a precisely controlled oxide layer of 2000 Å nominal thickness. (Fig. 10).
- The implanted resistors are defined next; a thin oxide layer is grown in the resistor geometries.
- The resistor is implanted using an 80 keV boron implantation. Note the resistor end caps are P +; also the boron implantation is through a thin oxide to prevent excessive surface damage. Figure 11 gives the resistor structure. Nominal sheet resistivity is 1000 ohms/square.

-2- FRONTSIDE PROCESSING - continued

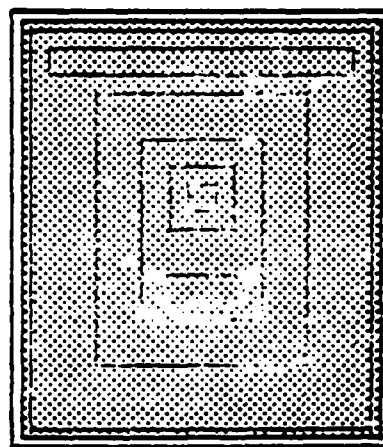
- Contact photoresist establishes apertures for ohmic contacts to the devices. (Fig. 12).
- A sample probe is performed next; device betas and breakdowns are checked.
- An E-beam evaporation of pure aluminum follows; metal thickness is 1.2μ . The layer is then delineated to form the interconnect pattern. (Fig. 3).
- A silox deposition follows; this CVD SiO_2 layer provides passivation and scratch protection. Openings to enable bonding are defined by a photoresist operation.
- A stabilization bake is next; it is followed by a detailed sample probe of device parameters and by backlap of the completed slice to a thickness of 10-12 units.



P Collector

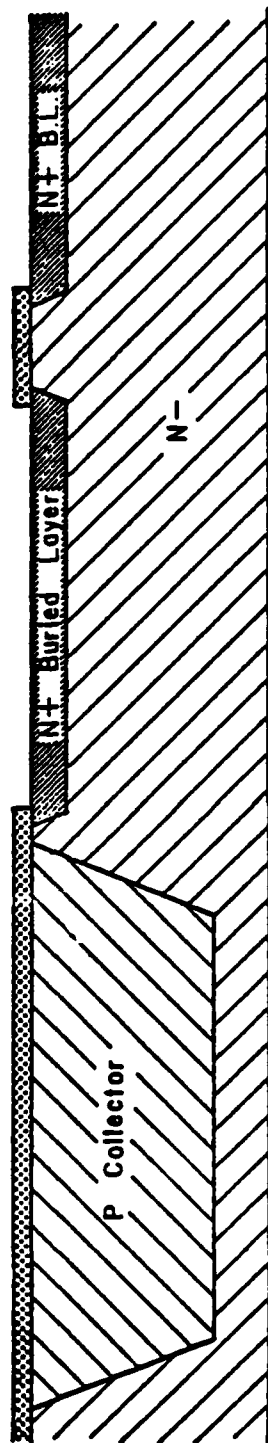


NPN

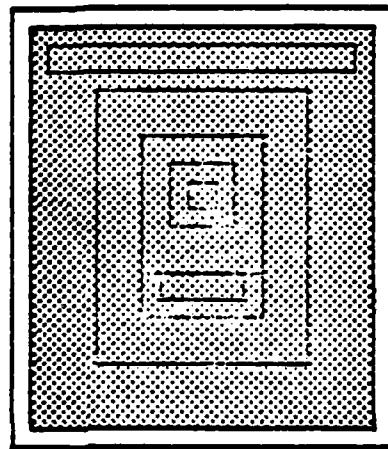
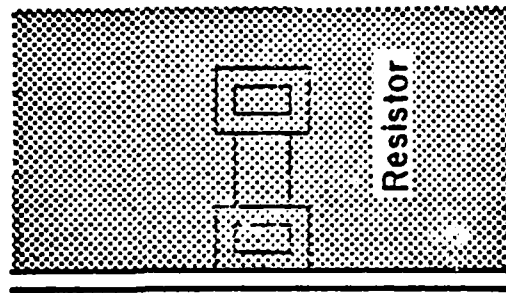


PNP

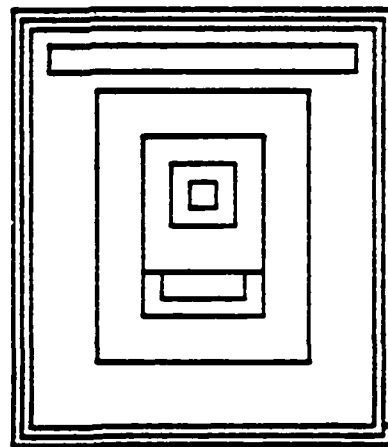
FIGURE 1



N+ Buried Layer

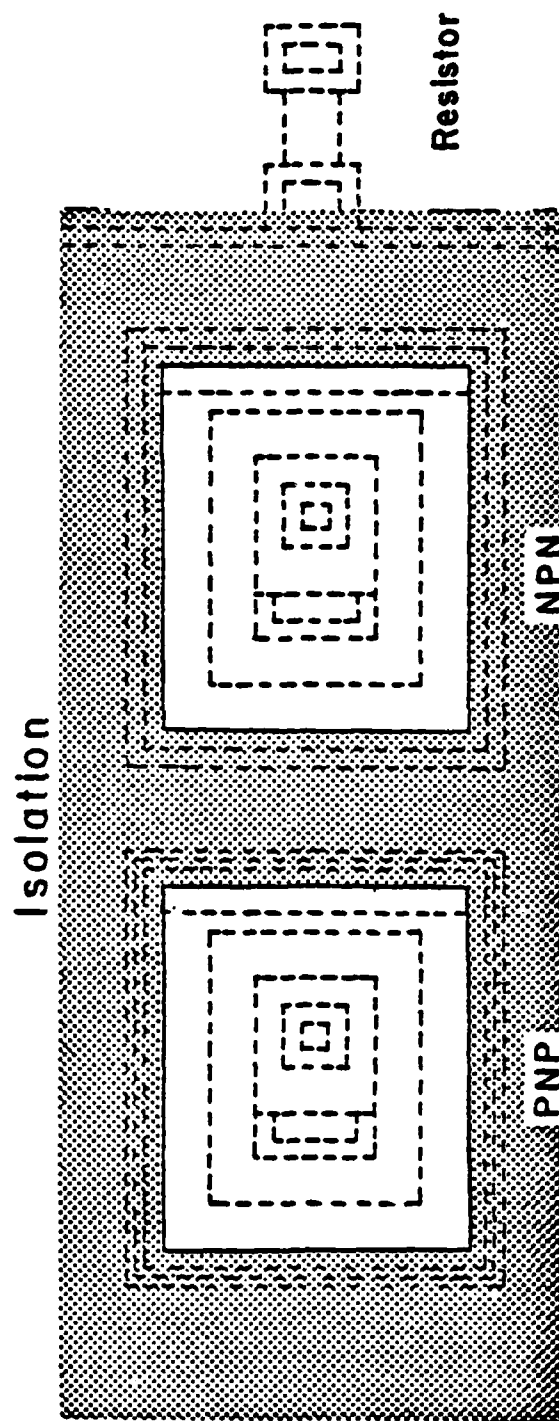
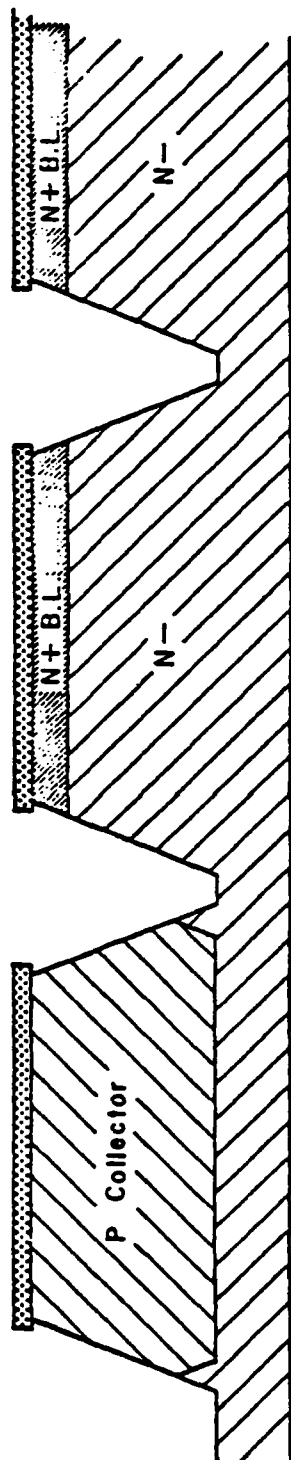


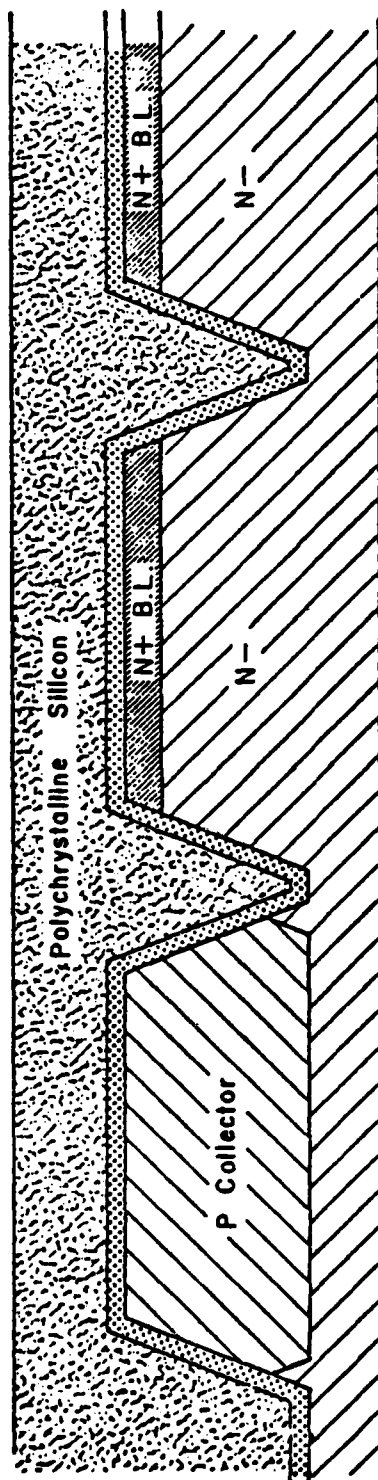
NPN



PNP

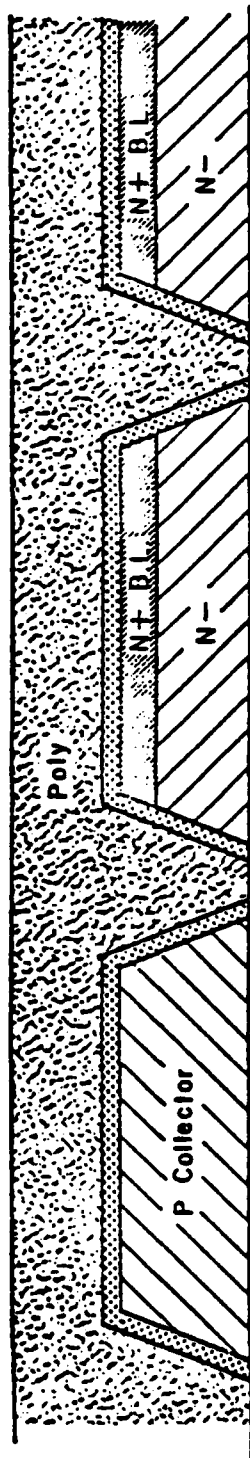
FIGURE 2





Grow Oxide in Moats, then add Poly for support.

FIGURE 4



Grind off excess material from N- side of slice.

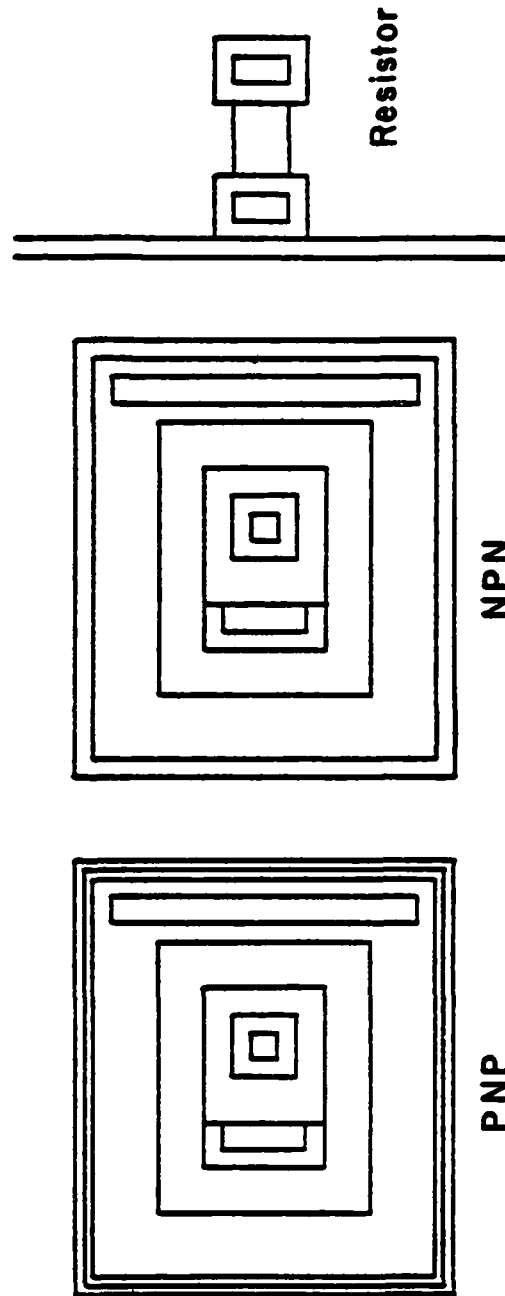
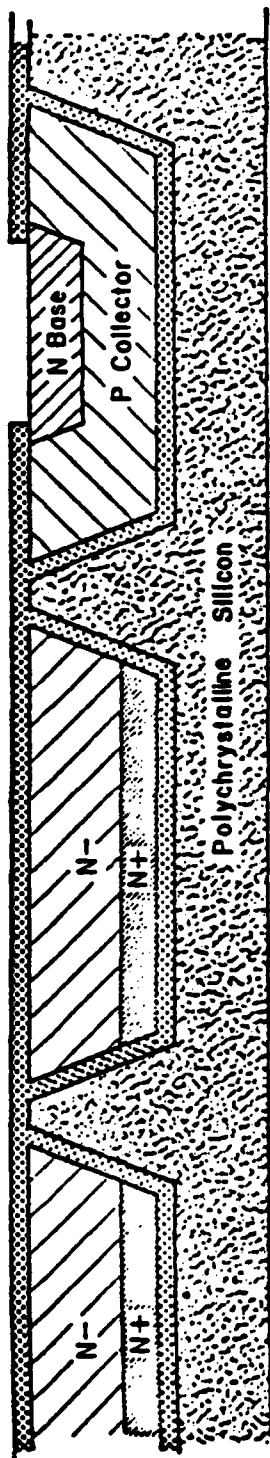
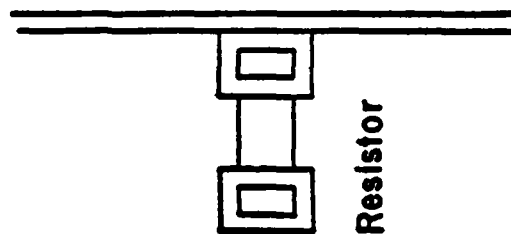


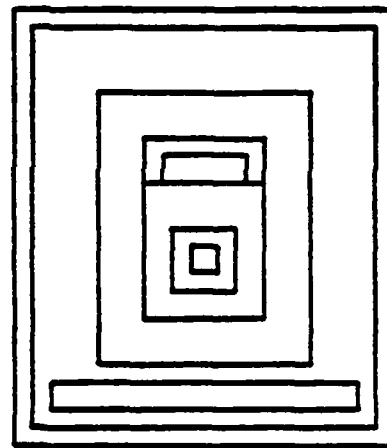
FIGURE 5



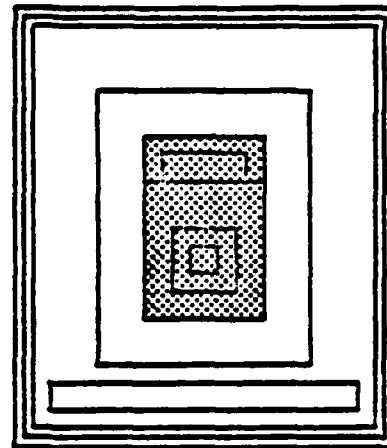
N Base



Resistor

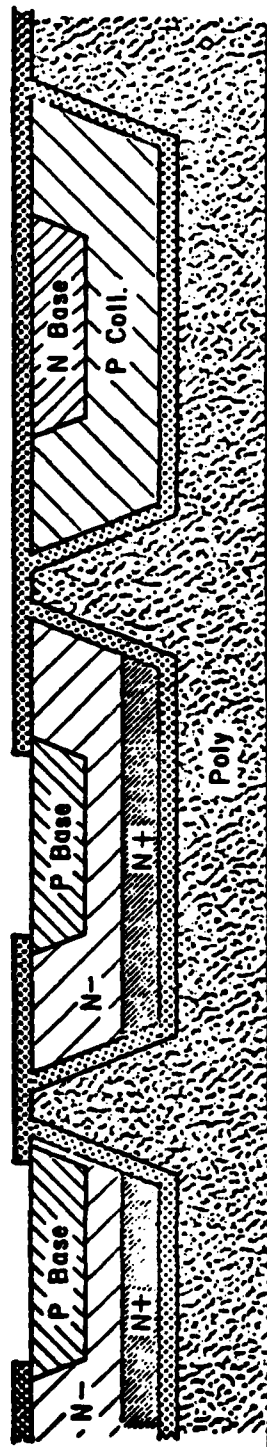


NPN

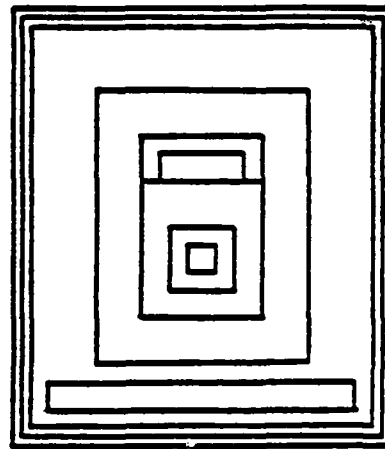
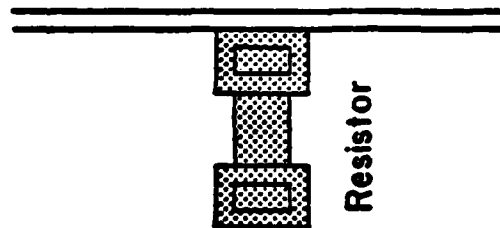


PNP

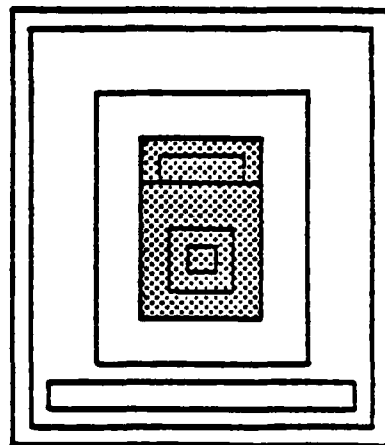
FIGURE 6



P Base

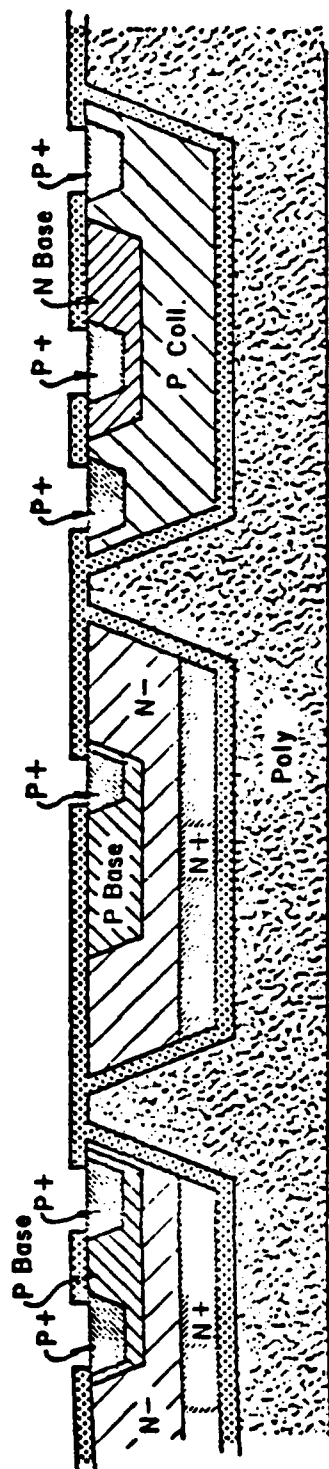


PNP

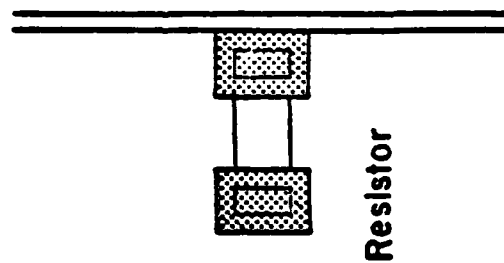


NPN

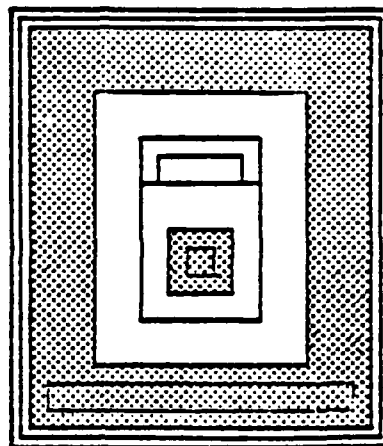
FIGURE 7



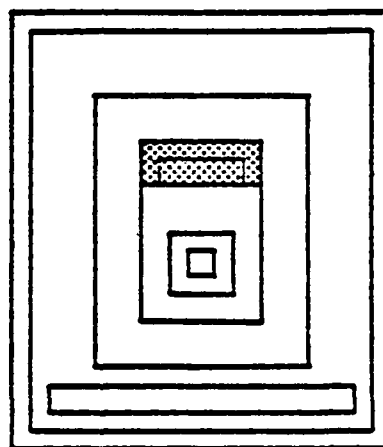
P+



Resistor

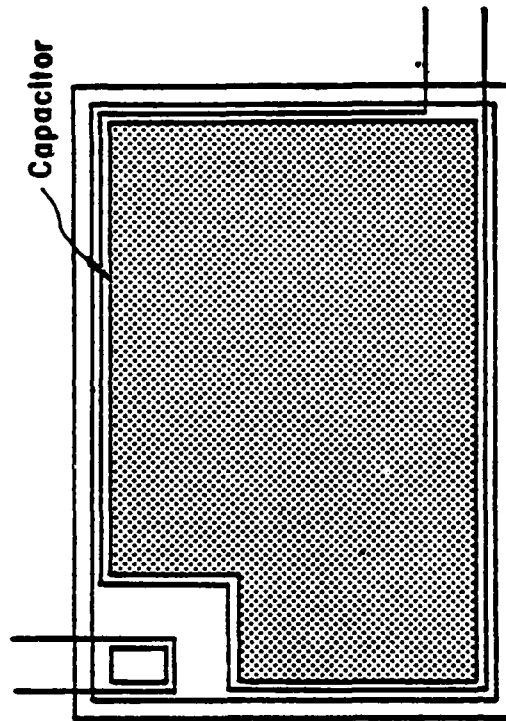
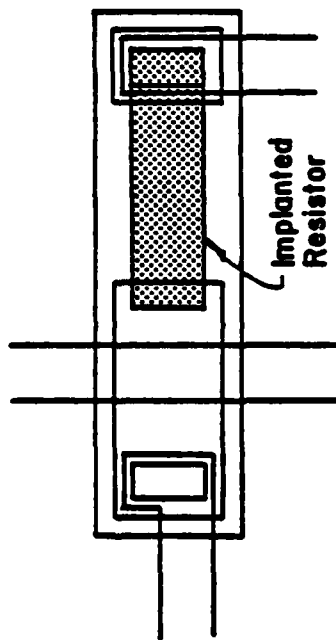
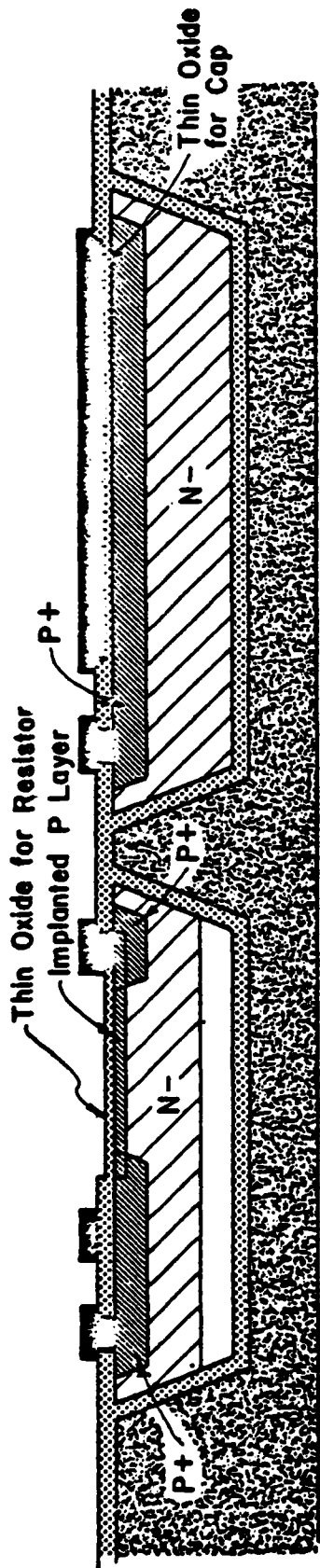


PNP



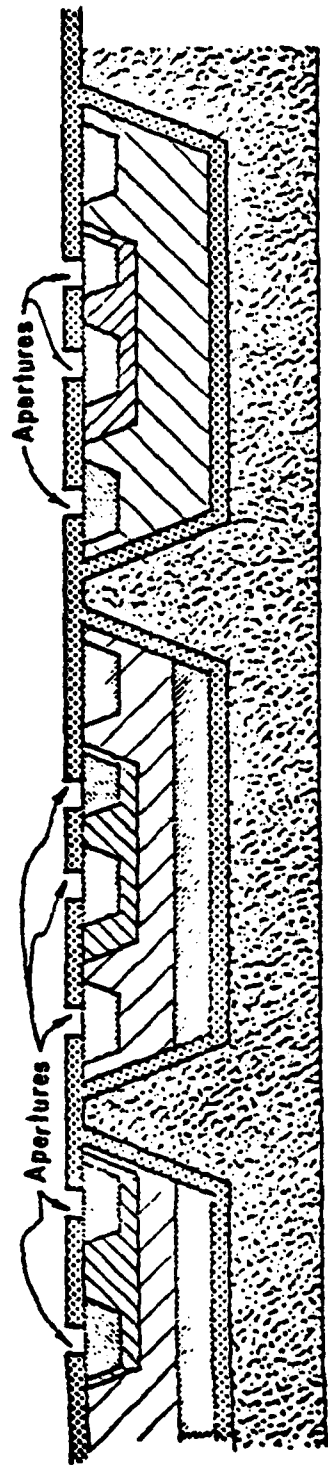
NPN

FIGURE 8

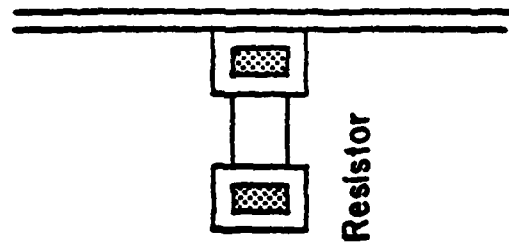


M.O.S. Capacitor

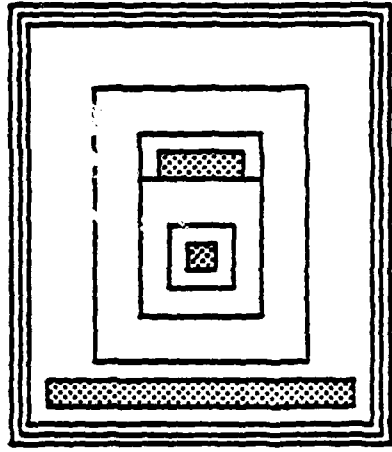
FIGURES 10 and 11



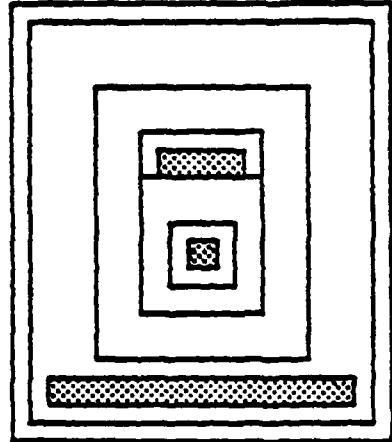
Apertures



Resistor

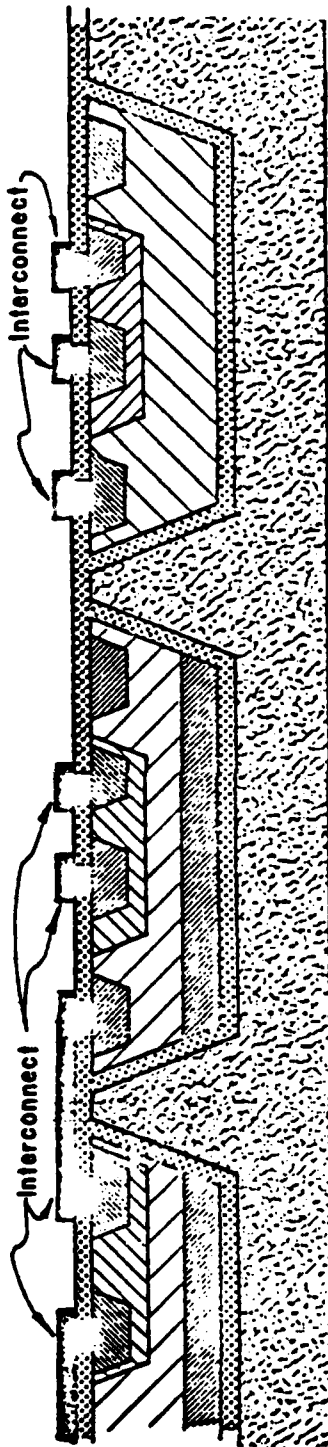


PNP



NPN

FIGURE 12



Aluminum Interconnect

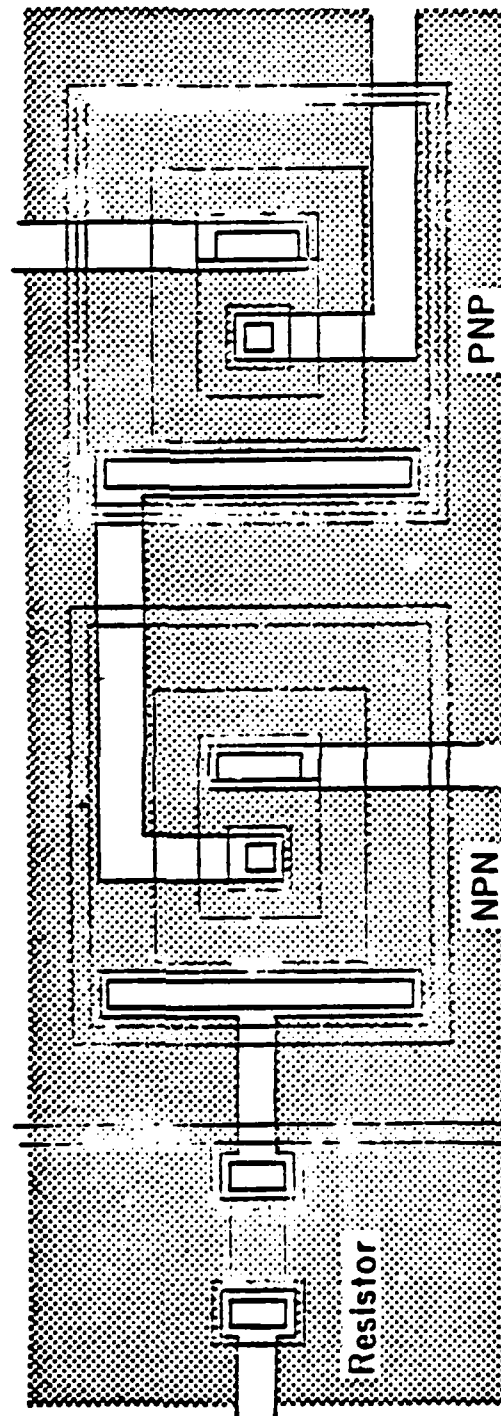


FIGURE 13

3.6 Radiation Effect Modeling

The crux of the radiation hardening effort of the DINS photopreamplifier lies in the structure of the two op amp stages. This structure resembles that of an advanced radiation hardened op amp now being developed by Harris' Programs Division. The fabrication of the preamp will be implemented by utilizing Harris' radiation hardened linear process.

Neutron and Total Dose Modeling

The primary effect of neutron and total dose radiation is a reduction in current gain and an increase in the resistivities of the lightly doped collector. At the radiation spec level of ϕ , minimum betas of 30 and 15 can be expected for the NPN and PNP devices respectively. The collector resistance of NPN devices increases by a factor of four and by a factor of 1.5 for the PNP. All post neutron computer simulations have taken these facts into account. A complete table of Gummel-Poon model parameters, both pre and post radiation can be found in the appendix of this report. These were used for SPICE II circuit simulation of the preamplifier under these conditions.

Transient Gamma Modeling

The predominant effect of a circuit's exposure to gamma radiation is the generation of electron-hole pairs within the space-charge regions of reversed biased junctions in the circuit. This generation of carriers causes a current, I_{pp} (primary photocurrent), to flow. These photocurrents may disrupt the normal operating conditions of the circuit sufficiently to cause a spurious output signal to be produced.

By the judicious placement of compensating reverse biased junctions on critical nodes, these photocurrent effects may be minimized. Figure 4 shows how this compensation scheme is used. Also shown are the polarities of the generated currents. In computer simulations of these photocurrents, current generators of appropriate magnitude (function of island volume) are placed in parallel with all reversed biased junctions including ion-implanted resistor islands. These islands are tied off to the more positive end of the resistor and depending on the voltage drop across the resistor, up to one half of the island volume may be depleted due to the voltage gradient set up across the resistor. With the generators in place, a transient simulation will show what effects the specified level of radiation will produce.

Computer sensitivity analyses show that the photocurrents generated by the reversed biased photodiode junctions at the input are the most critical. These are applied common mode to the preamplifier however any mismatch in photodiode volume implies a mismatch in photocurrent and this mismatch appears differentially across the input. Table 1 shows percent mismatch of photodiode volume versus signal to noise ratio. Note that this is assuming a perfect match between paired photocurrents elsewhere in the system. Also shown on Table 1 are typical signal to noise ratios for nominal system conditions.

Prompt Gamma Survival

Under very large γ environments, the major concern is to prevent either aluminum interconnect fusing or secondary junction burn-out due to surge currents (assuming all devices become shorts). This is accomplished in the preamplifier design by using limiting resistors RLIM1 through RLIM9. These are N+ resistors with a pre-radiation value of 50 ohms.

The secondary concern is the part's recovery time after such an event. A worst-case computer simulation has been performed using photo-current sources generating 100 milliamperes, 100 nanosecond wide pulses across every reversed biased junction in the circuit. The result of this simulation is shown in Figure 5. Under this condition, recovery time is in the order of 10 microseconds.

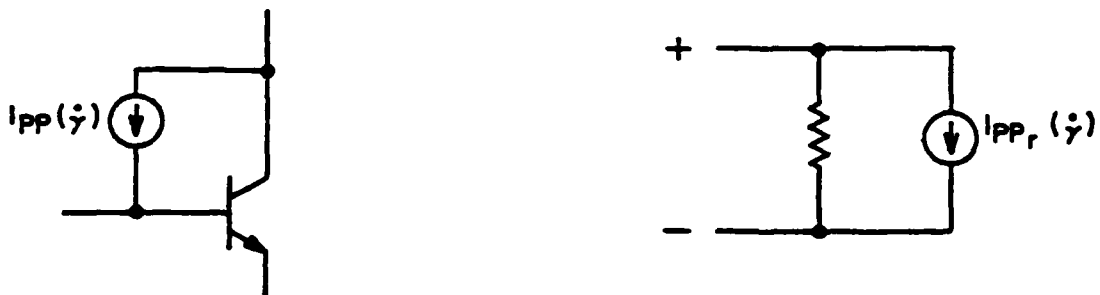
$\dot{\gamma}$ COMPUTER MODELING

THE GAMMA RADIATION CURRENT CAN BE CALCULATED FROM THE FOLLOWING EXPRESSION:

$$I_{pp}(\dot{\gamma}) = qg_0 \text{ Vol } \dot{\gamma}$$

$$\text{WHERE } g_0 = 4 \times 10^{13} / \text{rad-cm}^3$$

COMPUTER MODELS



TYPICAL COMPENSATION SCHEME

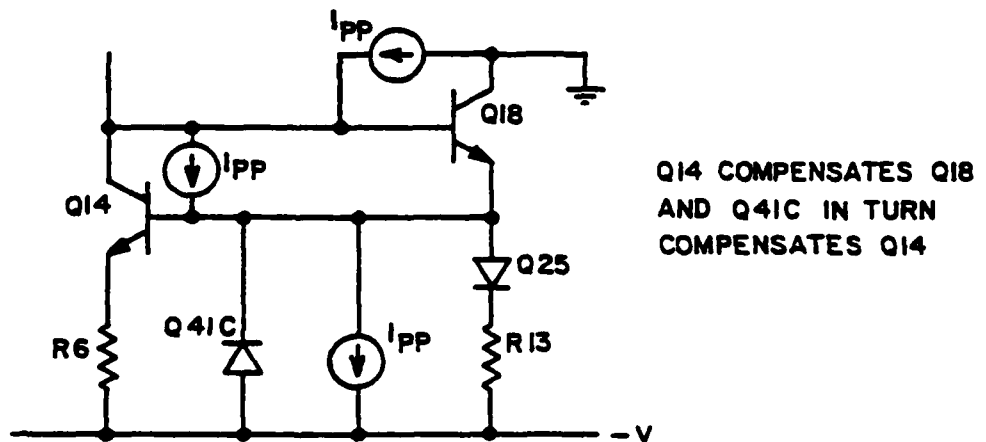


Figure 4

TABLE 1

- Assumptions: - Minimum input laser signal of 300 NW and spec radiation.
 - Four megohm nominal transimpedance
 - .44 amp/watt photodiode responsivity
 - 8.25 ua photodiode photocurrent
 - All other matching is absolute

<u>Signal to Noise Ratio</u>	<u>% Mismatch in Photodiode Volume</u>
1.6 to 1	1%
.8 to 1	2%
.53 to 1	3%
.4 to 1	4%
.32 to 1	5%

Under typical system conditions of twice the worst case minimum laser signal and a gamma rate level one order of magnitude less than the specification level.

<u>Signal to Noise Ratio</u>	<u>% Mismatch in Photodiode Volume</u>
32 to 1	1%
16 to 1	2%
10.6 to 1	3%
8 to 1	4%
6.4 to 1	5%

PROMPT GAMMA RECOVERY TIME

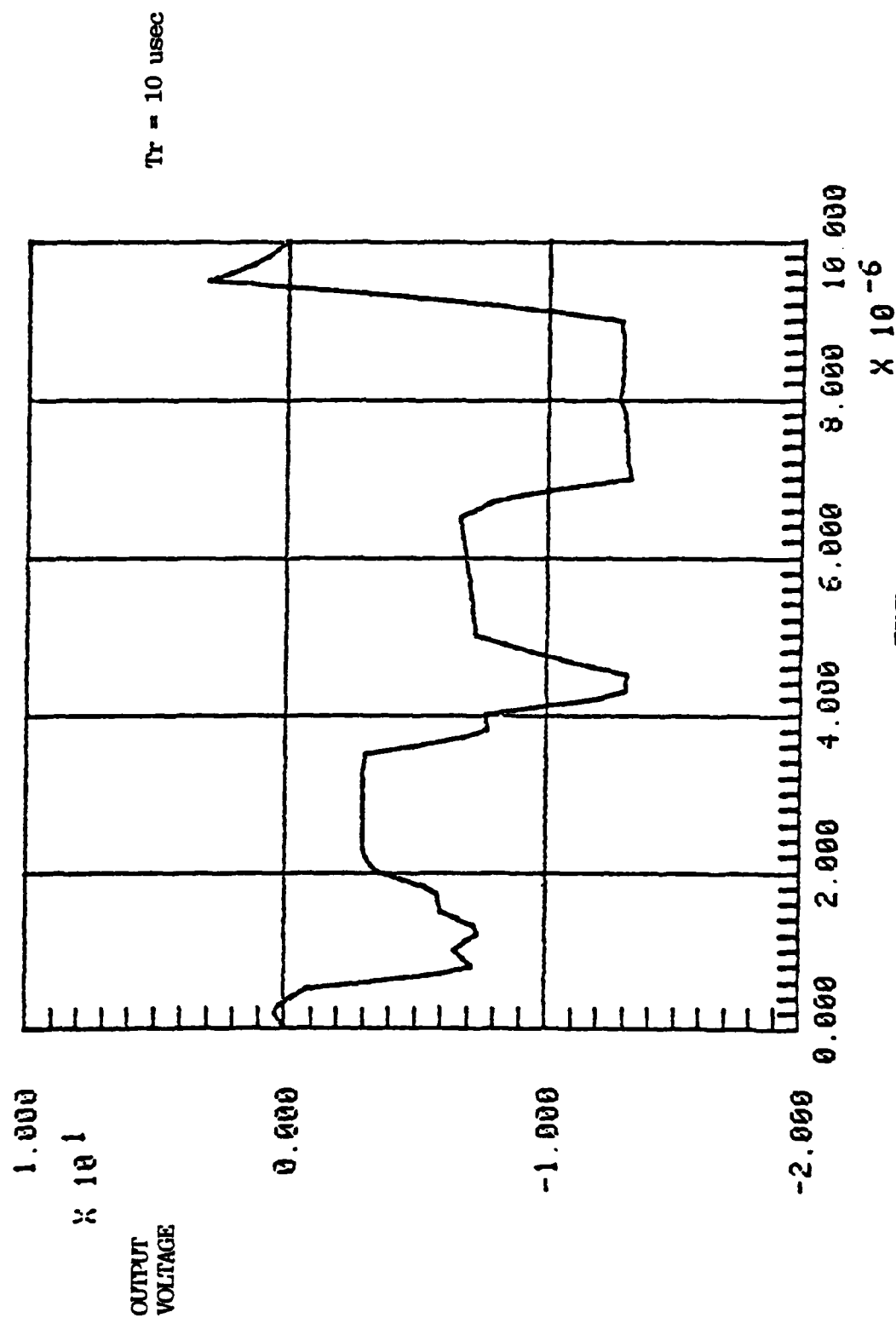
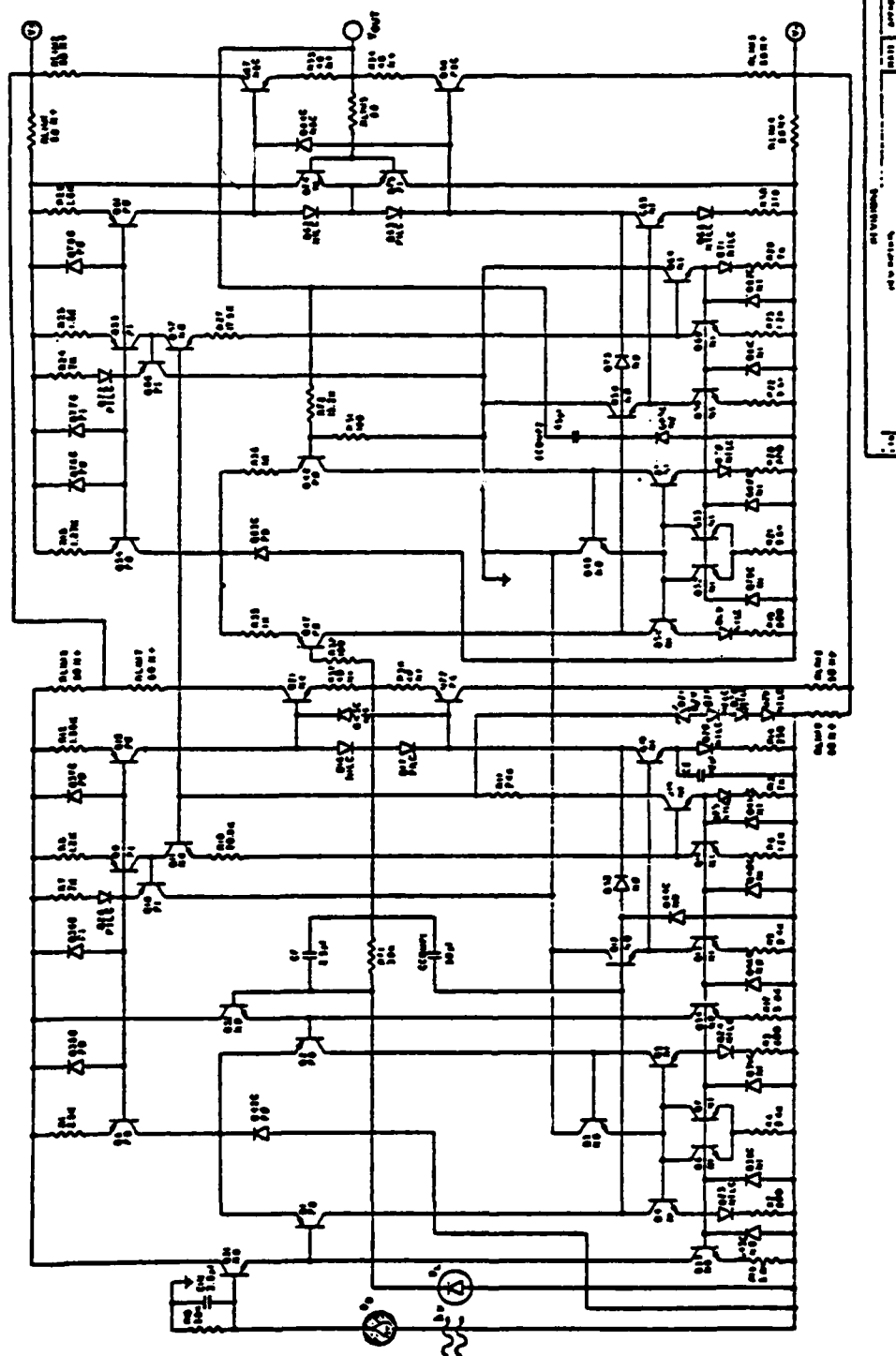


FIGURE 5

3.7 Thermal Noise Analysis

As previously stated, the noise signal generated as a result of a transient gamma event is the largest noise contributor in the system. However, for completeness a thermal noise analysis was performed over temperature to insure that these components were negligible. The simulation results showed the total output thermal noise voltage to be two orders of magnitude less than that generated by a 1% mismatch in photodiode volume. At 25°C the output noise voltage was 7 millivolts, 8.77 millivolts at 125°C and 6.5 millivolts at -55°C. Plots of output noise voltage squared versus frequency can be found in the appendix.



PHOTOAMPLIFIER SCHEMATIC

FIGURE 6

TABLE 2

TABLE OF ELEMENT VALUES

TABLE OF ELEMENT VALUES			
-----		RESISTORS	-----
NAME	VALUE		
R1	50E+03		
R2	2.80E+02		
R3	3.80E+02		
R4	3.40E+03		
R5	3.40E+03		
R6	1.20E+03		
R7	7.00E+03		
R8	1.20E+03		
R9 (RF1)	3.00E+04		
R10	2.05E+04		
R11	2.40E+04		
R12	1.35E+03		
R13	1.50E+03		
R14	2.50E+02		
R15	3.00E+04		
R16	5.80E+03		
R17	5.80E+03		
R18	1.27E+03		
R19	3.00E+02		
R20	3.00E+02		
R21	3.60E+03		
R22	3.60E+03		
R23	1.20E+03		
R24	1.50E+03		
R25 (RF2)	1.22E+04		
R26	1.75E+04		
R27			
R28			
R29			
R30			
R31			
R32			
R33			
R34			
R35			
R36			
R37			
R38			
RLIM1			
RLIM2			
RLIM3			
RLIM4			
RLIM5			
RLIM6			
RLIM7			
RLIM8			
RLIM9			
		-----	CAPACITORS
		-----	-----
	NAME	VALUE	
	CCOMP1	5.00E-11	
	CF	2.50E-12	
	CE	1.00E-11	
	CCOMP2	4.50E-13	
	CIN	2.50E-12	

4.0 CIRCUIT DESCRIPTION

4.1 General Overview

Shown in Figure 6 is the schematic diagram of the preamplifier. As mentioned earlier, the overall structure is that of two similar radiation hardened op amp stages in cascade. There are some variations between the two due to different gain-bandwidth products, stability requirements and short circuit protection requirements.

The transimpedance gain of the first stage A_1 is 30K and is set by feedback resistor RF1. Its closed loop bandwidth is set by the closed-loop pole obtained between RF1 and lead compensation capacitor CF. The bandwidth is a nominal value of 2 megahertz. Elements R15 and CIN are used to match the impedance seen at both input ports. This is important in order to minimize current induced voltage offset and also to balance the photocurrents generated at the input by these resistors. The open loop bandwidth of A_1 is set by COOMP1 and the gm of the input stage, using the classical dominant pole approach. It is a nominal value of 8 megahertz. Only 2 megahertz was required for the gain-bandwidth product of A_1 (voltage gain is unity in this stage) however any further reduction would require a larger value COOMP1. At its present value, the phase margin of the stage is greater than 45°. The value of COOMP1 is 50 pf (relatively large). Any further lowering of gm will increase the amplifier's photocurrent sensitivity due to the reduction in operating current in the input differential pair.

Figure 6 also shows the input photodiode D_L , and the compensating masked photodiode D_P . D_P is required to provide matched (common-mode) photocurrents to the preamplifier during a transient gamma event. D_P also assures a match in impedances seen by both input terminals. During circuit simulations both photodiodes were modelled as capacitors whose value was the sum of the diode's depletion and isolation capacitances. A worst case figure of 6 pf was used.

The second stage A_2 is a non-inverting amplifier in a gain of 133. The closed loop voltage gain is set by

$$\frac{RF2 + R31}{R31}$$

Resistor R32 matches the impedances seen by both input ports of A_2 . This resistor shall be a P+ resistor thereby generating very low radiation currents.

There are four ion-implanted resistors in the circuit whose islands shall not be tied off to the more positive side of the resistor. These are R15, RF1, RF2 and R31. Depending on the offset condition of A_1 and A_2 , these resistors may have voltages of either polarity across them. If they were tied off one could establish a forward biased junction between the P implant and the N - island.

Resistors R15 and RF1 shall be broken up into ten series connected 3K resistors in separate islands to limit the photocurrent contribution they generate to that of a single 3K resistor.

RF2, R31 COMPONENTS AT ION SCHEME

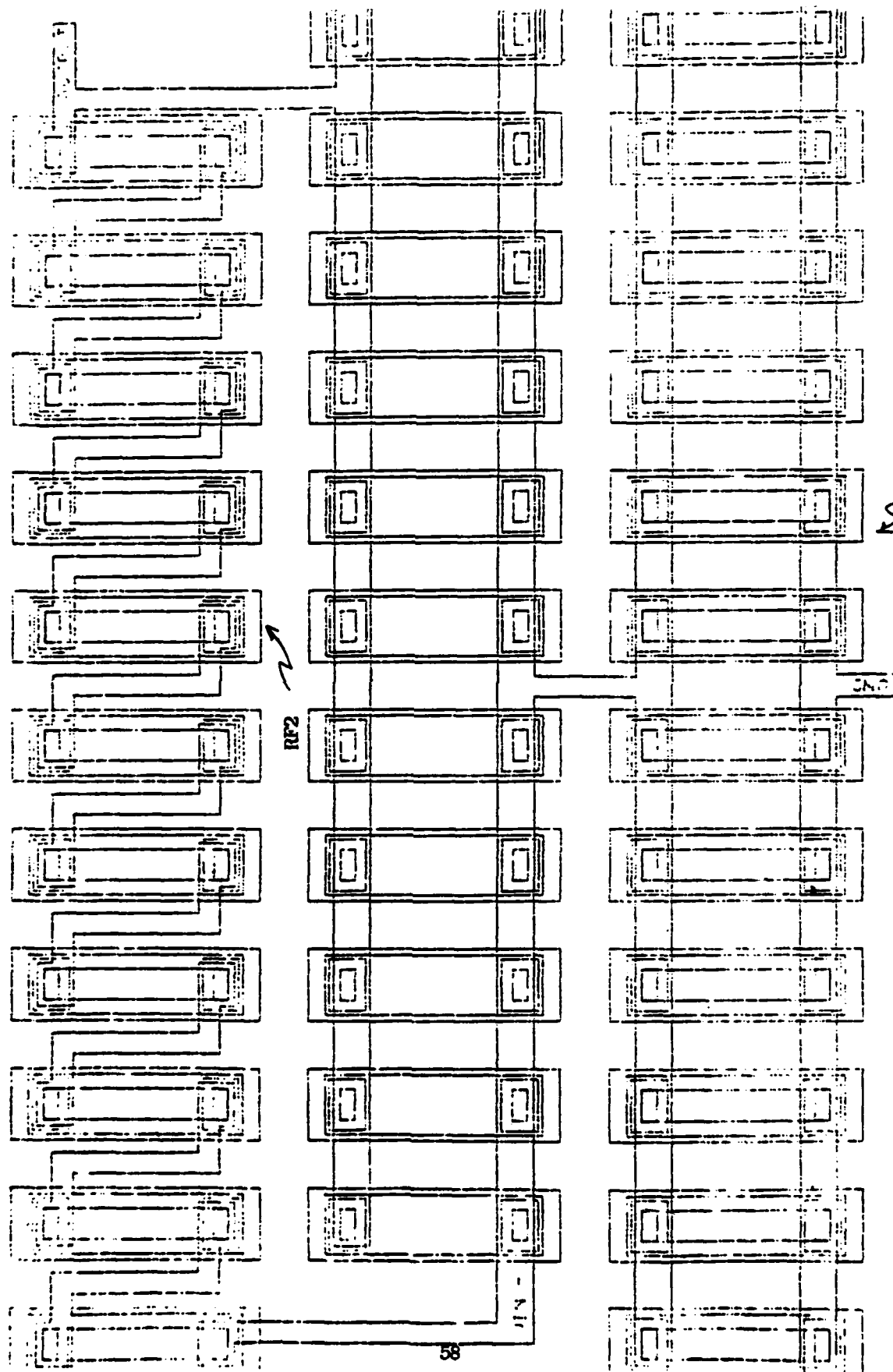


FIGURE 7

TABLE 3

ELECTRICAL PERFORMANCE

<u>GBW</u>	<u>REQUIRED</u>	<u>ACTUAL</u>
A ₁	2 mHz	8 mHz
A ₂	266 mHz	276 mHz

<u>ACTUAL</u> <u>POWER DISSIPATION (Two Channels)</u>	<u>TEMPERATURE</u>
212 Milliwatts	25°C
220 "	125°C
208 "	-55°C

AC STEADY-STATE OUTPUT VOLTAGE
(Assuming no offsets)

PRE-RAD	V out (SS AC) = 526 Millivolts
POST-RAD (Neutron Spec)	V out (SS AC) = 519 Millivolts

These outputs were obtained based on a minimum 300 nanowatt laser signal and a photodiode responsivity of .44 amps/watt. The corresponding steady state AC input signal used was 132 nanoamperes.

The case of resistors RF2 and R31 is more complex. These two resistors have significantly different values (RF2 = 13.2K and R31 = 100 ohms) however since they set the gain of A₂ they must ratio. In addition, their photocurrent generation must be mutually compensating in order that no differential voltage appears at A₂'s input. The approach that was chosen dictated RF2 to be built as eleven 1.2K series connected resistors in separate islands and R31 to be twelve 1.2K parallel connected resistors in separate islands. This resolves the ratio tracking problem but leaves R31 generating twelve times the photocurrent of RF2. This was resolved by paralleling eleven dummy islands, whose volume matches that of a 1.2K resistor, with RF2. A summary of this compensation scheme is shown in Figure 7.

A gain of 133 for A₂ implies this stage must have a gain-bandwidth product of greater than 250 megahertz. This figure would be unreasonable if the amplifier were required to be stable at a closed loop gain of unity. However at a gain of 133, greater than 45 degrees of phase margin has been achieved. Emitter degeneration resistors R35 and R36 tend to reduce the gm of the input stage. However they are required to aid in the stability of A₁. The gm of A₂'s input stage is

$$g_m = \frac{1}{R_{35} + 2 \frac{KT}{q \cdot I_{Q47}}}$$

The collector current of Q47 is 185 microamps and therefore gm is 780 microhms. Gain-bandwidth product is defined as

$$GBW = \frac{g_m}{2\pi C}$$

Here C is element COOMP2 or .45 pf therefore the gain-bandwidth product of A₂ is 276 megahertz.

When reading the system schematic, all device names with a trailing C in the name are photocurrent compensation devices and are reverse biased.

TABLE 3 lists gain-bandwidth requirements, actual total power dissipation and actual pre and post radiation steady-state output voltages.

4.2 Biasing

Both stages A₁ and A₂ are biased from a common voltage reference consisting of D21, Q27, Q28 and Q29 however each stage maintains its own isolated NPN and PNP base biasing rails. R24 sets up current of 275 ua to bias the zener QN. Devices Q11 and Q57 then set up reference currents for the four independent base rails located at the bases of Q9, Q14, Q55 and Q60.

4.3 Input Stages

The inputs stages of A₁ and A₂ differ in structure. For A₁ an NPN/PNP modified Darlington configuration was chosen (Q31-Q1 and Q32-Q2). The necessity for this type of configuration here is due to post-neutron bandwidth reduction due to a lowering of gm. The expression for gm of a differential pair is

$$g_m = 2 \frac{1}{\left[\frac{r_b + R_s + r_e}{\beta_n} \right]}$$

Where r_b is the base spreading resistance, r_e is the dynamic input impedance and R_s is a source impedance. For a radiation insensitive g_m it is desirable that the second term be dominant since it is not beta dependent. If a simple differential pair were used, R_s would actually be R_{15} or R_{F1} (30K). Therefore under post radiation conditions, betas would not be large enough to adequately swamp out this term. Using the Darlington approach, the g_m expression is

$$g_m = \frac{1}{2 \left[\frac{r_{b1} + R_s + r_{b31}}{\beta_p} + r_{e1} \right] \beta_n}$$

and the R_s term now is effectively buffered.

The input stage of A_2 sees a low source impedance. At the non-inverting input this consists of R_{32} in series with the output of A_1 and approximately R_{31} in parallel with R_{F2} at the inverting input. Therefore a simple differential pair was chosen. Upon initial simulation of the open loop gain of A_1 a 10 DB gain peak was detected around 50 megahertz. The peak was caused by the fact that at 50 megahertz the feedback factor of A_2 was low enough that A_2 's input impedance began to look capacitive. At the same time, at high frequencies, the impedance looking into the emitter of a follower stage emulates an inductor. This creates a now well known tank circuit effect. Two changes were the key to the removal of the peak to obtain the smooth roll-off characteristics presently seen. First, emitter degeneration resistors R_{35} and R_{36} were used to increase the real part of A_2 's input impedance. Second, capacitor C_E in A_1 in parallel with the dynamic impedance of Q_{20} plus R_{14} generates a zero in the transfer function. The combined effect of these two elements assures the stability of A_1 with a simulated phase margin of 65 degrees.

4.4 Active Loads and Gain Stages.

The input stage current mirrors used in A_1 and A_2 are modifications of the classic Widlar current mirror. In A_1 devices Q_3 - Q_4 - Q_5 - Q_6 and Q_7 form the mirror. Q_5 is essentially diode connected by the base-emitter junction of Q_3 . The parallel combination of Q_6 - Q_7 draw out Q_3 's emitter current from the base rail of the mirror. Note that devices Q_6 and Q_7 have the same areas as Q_4 and Q_5 and therefore serve as photocompensation devices. Device Q_{12} serves as a buffer between the mirror and the gain stage Q_{19} . Q_{12} is biased at the same current as Q_3 so the base currents they rob from the collectors of Q_4 - Q_5 are equal.

Q_{12} and Q_{19} form the gain stage of A_1 . Capacitor C_{COMP1} performs the pole-splitting action of the integrator. Note that this capacitor ties to the output of A_1 and not to the collector of Q_{19} . Simulations show a greater degree of phase margin is achievable using this approach.

4.5 Output Stage and Short Circuit Protection

Both A_1 and A_2 use the standard class AB output stage found on most op amps used today. The output stage of A_2 differs from that of A_1 in operating current and device size. Also, A_2 incorporates a short circuit protection scheme using Q_{74} and Q_{75} . Since system specifications required A_2 to drive a

coaxial cable, a parallel RC load was used throughout the simulations. The value of R was 2K and C was 100 pf. The large output devices and operating points help source and sink the larger currents necessary to drive such a load.

Under short circuit conditions, large currents may initially flow through resistors R33 or R34 (depending on the direction of the short). If the drop across R33 reaches one diode drop, device Q75 turns on and robs driving current from the gain stage. A similar condition of opposite polarity causes a similar effect from R34 and Q74.

4.6 Breadboard Simulation Results

Shown in Figure 7 is the block diagram of the breadboard version of the photopreamplifier. For the transimpedance stage, the afore mentioned radiation hardened op amp (913) was used. This part is internally compensated and has a gain bandwidth product of 10 megahertz. For this reason it was not feasible to use this op amp for the second stage since in the breadboard version this stage requires a gain bandwidth product of 100 megahertz ($BW = 1 \text{ mHz}$ at a gain of 100). Instead, a commercial op amp, the HA5190 manufactured by Harris' Products Division was used. This part has a gain bandwidth product of 150 megahertz but is not radiation hardened.

The purpose of constructing the printed-circuit board version of the system was to see if the required overall transimpedance of 3 megohms and a 1 megahertz bandwidth could be achieved without instability. Also the circuit was to be used to amplify signals from prototype photodiodes whose fabrication was near completion. The results achieved were very good. A spectrum analyser showed the gain at 3.1 megohms and a bandwidth of 1.5 megahertz. The laser light used to drive the photodiodes was modulated by a 100 kilohertz square wave using a quartz modulator and the diodes output was properly amplified by the breadboard preamplifier.

DINS PHOTOPREAMP BREADBOARD

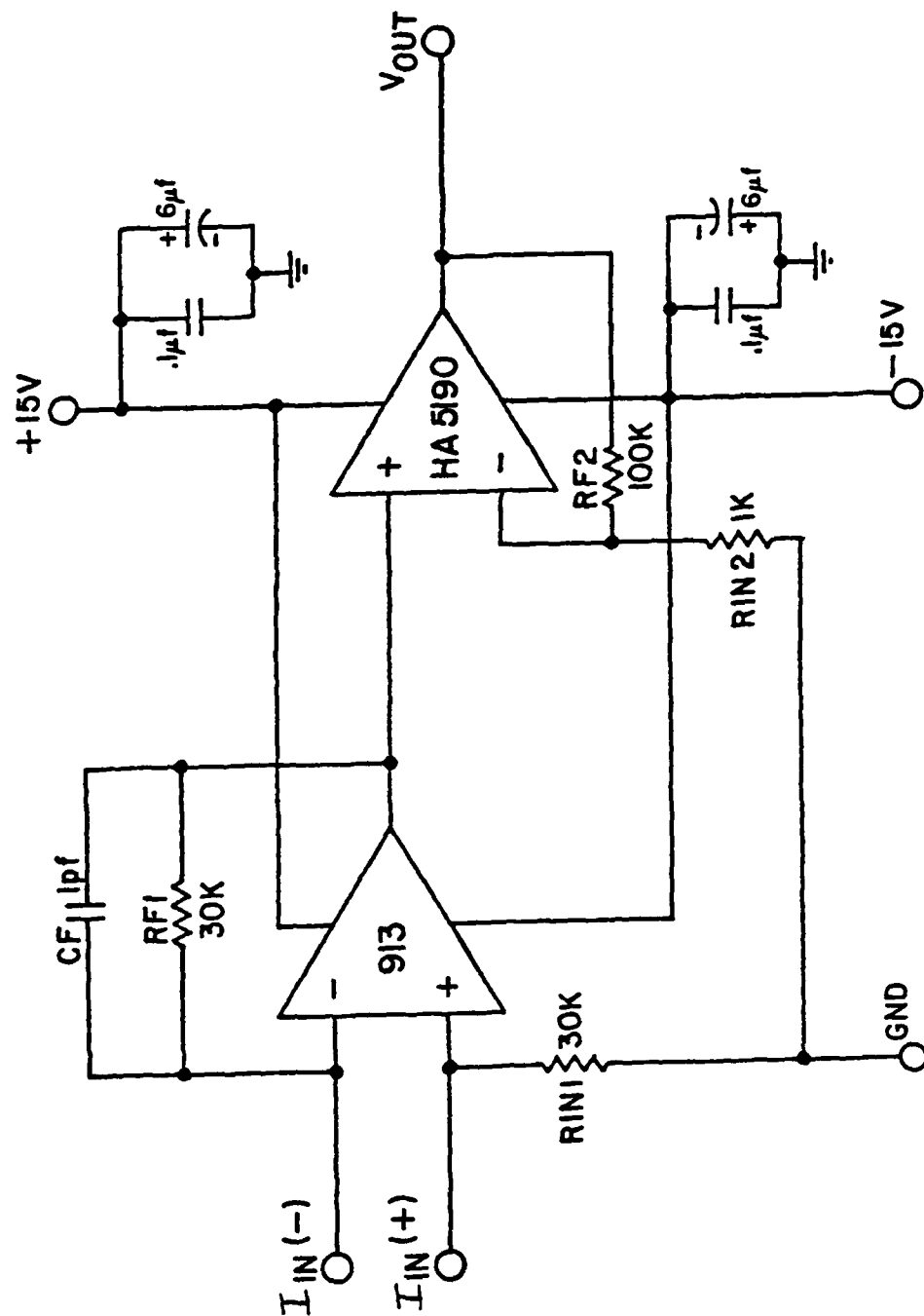


Figure 8

5.0 Conclusion

A design approach and a method of implementation has been presented. Computer circuit simulations have verified that the DINS photodetector will meet gain and bandwidth specifications over temperature and process variation. In addition the part will be able to meet these requirements after exposure to neutron fluence of the spec level. Simulations also show the preamplifier's ability to drive a capacitive load without instability and its indefinite tolerance to an output short circuit. The photodetector is also hardened to withstand a transient gamma event of the specified level. This is the single most critical spec of the system and is also the most difficult to achieve. As can be seen from Table 1, only 1% match in photodiode volume will provide a signal to noise ratio greater than 1 to 1. Statistical data (from a different process) shows 5% matching to be an achievable tolerance, however, at this level the signal to noise ratio is short of spec by a factor of three. It was stated during the status meeting held on June 7th that a γ level of one order of magnitude less than spec would be representative of what the photodetector would experience. Under this condition, a 5% mismatch in photodiode volume implies a signal to noise ratio of 3.2 to 1 or a factor of three greater than spec. We feel that this level of γ is a more realistic figure to expect the photodetector to tolerate.

The design presented here has been the combined effort of many individuals whose skills range from computer-aided design to state of the art process enhancement. It is our belief that provided the above compromise in spec is assured, the DINS photodetector effort holds a great chance for success.

APPENDIX 1.0

MODEL PARAMETERS

1.1 PRE-RADIATION PARAMETERS

1.2 POST NEUTRON PARAMETERS

PRE-RADIATION GUMMEL-POON MODEL PARAMETERS FOR SPICE II CIRCUIT
 SIMULATION OF THE DINS PHOTOPREAMPLIFIER (TEMPERATURE 25 DEGREES C)

----- BJT MODELS -----				
NAME	TYPE			
RN1LC NPN				
BF=	2.000E+02	BR=	9.000E+00	IS=
RC=	4.040E+02	RE=	0.000E+00	UA=
IK=	5.000E-02	C2=	6.000E+02	NE=
C4=	4.520E+02	NC=	1.450E+00	TF=
CCS=	4.500E-13	CJE=	8.200E-13	PE=
CJC=	8.000E-13	PC=	4.700E-01	MC=
				RB=
				UB=
				IKR=
				TR=
				ME=
				EG=
RP1LC PNP				
BF=	1.500E+02	BR=	9.000E+00	IS=
RC=	5.000E+02	RE=	0.000E+00	UA=
IK=	5.000E-02	C2=	6.000E+02	NE=
C4=	4.520E+02	NC=	1.450E+00	TF=
CCS=	4.500E-13	CJE=	9.500E-13	PE=
CJC=	8.600E-13	PC=	3.500E-01	MC=
				RB=
				UB=
				IKR=
				TR=
				ME=
				EG=
RN0 NPN				
BF=	2.000E+02	BR=	9.000E+00	IS=
RC=	1.053E+03	RE=	0.000E+00	UA=
IK=	2.500E-02	C2=	6.000E+02	NE=
C4=	4.520E+02	NC=	1.450E+00	TF=
CCS=	2.000E-13	CJE=	4.500E-13	PE=
CJC=	5.400E-13	PC=	4.700E-01	MC=
				RB=
				UB=
				IKR=
				TR=
				ME=
				EG=

RN1 NPN
BF= 3.000E+02
RC= 6.910E+02
IK= 5.000E-02
C4= 4.520E+02
CS= 2.500E-13
CJC= 8.000E-13

BR= 9.000E+00
RE= 0.000E+00
C2= 6.000E+02
NC= 1.450E+00
CJE= 8.200E-13
PC= 4.700E-01

IS= 1.000E-15
UA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 8.400E-01
MC= 2.100E-01

RB= 3.200E+02
UB= 2.000E+01
IKR= 1.000E-02
TR= 7.500E-08
ME= 3.700E-01
EG= 1.110E+00

RN4 NPN
BF= 2.000E+02
RC= 1.750E+02
IK= 2.000E-01
C4= 4.520E+02
CS= 4.400E-13
CJC= 2.300E-12

BR= 9.000E+00
RE= 0.000E+00
C2= 6.000E+02
NC= 1.450E+00
CJE= 3.200E-12
PC= 4.700E-01

IS= 4.000E-15
UA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 8.400E-01
MC= 2.100E-01

RB= 1.590E+02
UB= 2.000E+01
IKR= 4.000E-02
TR= 7.500E-08
ME= 3.700E-01
EG= 1.110E+00

RN8C NPN
BF= 2.000E+02
RC= 8.000E+01
IK= 4.000E-01
C4= 4.520E+02
CS= 1.200E-12
CJC= 3.800E-12

BR= 9.000E+00
RE= 0.000E+00
C2= 6.000E+02
NC= 1.450E+00
CJE= 6.200E-12
PC= 4.700E-01

IS= 8.000E-15
UA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 8.400E-01
MC= 2.100E-01

RB= 9.500E+01
UB= 2.000E+01
IKR= 3.000E-02
TR= 7.500E-08
ME= 3.700E-01
EG= 1.110E+00

RP0 PNP
BF= 1.500E+02
RC= 1.428E+03
IK= 2.500E-02
C4= 4.520E+02
CS= 2.000E-13
CJC= 6.000E-13

BR= 9.000E+00
RE= 0.000E+00
C2= 6.000E+02
NC= 1.450E+00
CJE= 5.200E-13
PC= 3.500E-01

IS= 3.500E-16
UA= 6.000E+01
NE= 2.000E+00
TF= 3.500E-10
PE= 6.900E-01
MC= 3.300E-01

RB= 3.000E+02
UB= 3.000E+01
IKR= 5.000E-03
TR= 4.000E-07
ME= 2.600E-01
EG= 1.110E+00

RP1 PNP
 BF= 1.500E+02
 RC= 1.040E+03
 IK= 5.000E-02
 C4= 4.520E+02
 CCS= 2.500E-13
 CJC= 8.600E-13
 BR= 9.000E+00
 RE= 0.000E+00
 C2= 6.000E+02
 NC= 1.450E+00
 CJE= 9.500E-13
 PC= 3.500E-01
 IS= 7.000E-16
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 6.900E-01
 MC= 3.300E-01
 RB= 2.500E+02
 UB= 2.000E+01
 IKR= 1.000E-02
 TR= 4.000E-07
 ME= 2.600E-01
 EG= 1.110E+00

RP4 PNP
 BF= 1.500E+02
 RC= 2.600E+02
 IK= 2.000E-01
 C4= 4.520E+02
 CCS= 4.400E-13
 CJC= 2.500E-12
 BR= 9.000E+00
 RE= 0.000E+00
 C2= 6.000E+02
 NC= 1.450E+00
 CJE= 3.700E-12
 PC= 3.500E-01
 IS= 2.800E-15
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 6.900E-01
 MC= 3.300E-01
 RB= 7.500E+01
 UB= 2.000E+01
 IKR= 4.000E-02
 TR= 4.000E-07
 ME= 2.600E-01
 EG= 1.110E+00

RP8C PNP
 BF= 1.500E+02
 RC= 1.160E+02
 IK= 4.000E-01
 C4= 4.520E+02
 CCS= 1.200E-12
 CJC= 4.000E-12
 BR= 9.000E+00
 RE= 0.000E+00
 C2= 6.000E+02
 NC= 1.450E+00
 CJE= 7.300E-12
 PC= 3.500E-01
 IS= 5.600E-15
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 6.900E-01
 MC= 3.300E-01
 RB= 3.700E+01
 UB= 2.000E+01
 IKR= 3.000E-02
 TR= 4.000E-07
 ME= 2.600E-01
 EG= 1.110E+00

----- ZENER DIODE MODEL -----

NAME
 DZR
 IS= 5.000E-16
 CJO= 4.500E-13
 PT= 3.000E+00
 BV= 6.200E+00
 RS= 7.500E+01
 PB= 8.400E-01
 KF= 0.000E+00
 IBV= 5.000E-04
 TT= 1.400E-10
 EQ= 1.110E+00
 FC= 5.000E-01

(TEMPERATURE 125 DEGREES C)

----- BJT MODELS -----
NAME TYPE

RH1LC NPN
BF= 2.500E+02
RC= 8.030E+02
IK= 5.000E-02
C4= 4.101E+01
CCS= 4.500E-13
CJC= 8.000E-13
BR= 1.224E+01
RE= 0.000E+00
C2= 1.789E+00
NC= 1.450E+00
CJE= 8.200E-13
PC= 2.700E-01
IS= 1.125E-10
UA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 6.400E-01
MC= 2.100E-01
RB= 3.840E+02
UB= 2.000E+01
IKR= 1.000E-02
TR= 1.150E-07
ME= 3.700E-01
EG= 1.110E+00

RP1LC PNP
BF= 1.950E+02
RC= 1.000E+03
IK= 5.000E-02
C4= 4.101E+01
CCS= 4.500E-13
CJC= 8.600E-13
BR= 1.062E+01
RE= 0.000E+00
C2= 1.789E+00
NC= 1.450E+00
CJE= 9.500E-13
PC= 1.500E-01
IS= 7.873E-11
UA= 6.000E+01
NE= 2.000E+00
TF= 3.500E-10
PE= 4.900E-01
MC= 3.300E-01
RB= 3.000E+02
UB= 2.000E+01
IKR= 1.000E-02
TR= 5.200E-07
ME= 2.600E-01
EG= 1.110E+00

RN0 NPN
BF= 2.500E+02
RC= 2.106E+03
IK= 2.500E-02
C4= 4.101E+01
CCS= 2.000E-13
CJC= 5.400E-13
BR= 1.224E+01
RE= 0.000E+00
C2= 1.789E+00
NC= 1.450E+00
CJE= 4.500E-13
PC= 2.700E-01
IS= 5.624E-11
UA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 6.400E-01
MC= 2.100E-01
RB= 4.668E+02
UB= 2.000E+01
IKR= 5.000E-03
TR= 1.150E-07
ME= 3.700E-01
EG= 1.110E+00

RN1	2.500E+02	BR=	1.224E+01	IS=	1.125E-10	RB=	3.840E+02
BF=	1.382E+03	RE=	0.000E+00	VA=	7.500E+01	UB=	2.000E+01
RC=	5.000E-02	C2=	1.789E+00	NE=	2.000E+00	IKR=	1.000E-02
IK=	4.101E+01	NC=	1.450E+00	TF=	1.400E-10	TR=	1.150E-07
C4=	2.500E-13	CJE=	8.200E-13	PE=	6.400E-01	ME=	3.700E-01
CCS=	6.000E-13	PC=	2.700E-01	MC=	2.100E-01	EG=	1.110E+00
CJC=							
RN4	2.500E+02	BR=	1.224E+01	IS=	4.499E-10	RB=	1.908E+02
BF=	3.500E+02	RE=	0.000E+00	VA=	7.500E+01	UB=	2.000E+01
RC=	2.000E-01	C2=	1.789E+00	NE=	2.000E+00	IKR=	4.000E-02
IK=	4.101E+01	NC=	1.450E+00	TF=	1.400E-10	TR=	1.150E-07
C4=	4.400E-13	CJE=	3.200E-12	PE=	6.400E-01	ME=	3.700E-01
CCS=	2.300E-12	PC=	2.700E-01	MC=	2.100E-01	EG=	1.110E+00
CJC=							
RN8C	2.500E+02	BR=	1.224E+01	IS=	8.998E-10	RB=	1.140E+02
BF=	1.600E+02	RE=	0.000E+00	VA=	7.500E+01	UB=	2.000E+01
RC=	4.000E-01	C2=	1.789E+00	NE=	2.000E+00	IKR=	8.000E-02
IK=	4.101E+01	NC=	1.450E+00	TF=	1.400E-10	TR=	1.150E-07
C4=	1.200E-12	CJE=	6.200E-12	PE=	6.400E-01	ME=	3.700E-01
CCS=	3.800E-12	PC=	2.700E-01	MC=	2.100E-01	EG=	1.110E+00
CJC=							
RP0	1.950E+02	BR=	1.062E+01	IS=	3.937E-11	RB=	3.600E+02
BF=	2.856E+03	RE=	0.000E+00	VA=	6.000E+01	UB=	2.000E+01
RC=	2.500E-02	C2=	1.789E+00	NE=	2.000E+00	IKR=	5.000E-03
IK=	4.101E+01	NC=	1.450E+00	TF=	3.500E-10	TR=	5.200E-07
C4=	2.000E-13	CJE=	5.500E-13	PE=	4.900E-01	ME=	2.600E-01
CCS=	6.000E-13	PC=	1.500E-01	MC=	3.300E-01	EG=	1.110E+00
CJC=							

RP1 PNP
 BF= 1.950E+02
 RC= 3.080E+03
 IK= 5.000E-02
 C4= 4.101E+01
 CCS= 2.500E-13
 CJC= 8.600E-13

BR= 1.062E+01
 RE= 0.000E+00
 C2= 1.789E+00
 NC= 1.450E+00
 CJE= 9.500E-13
 PC= 1.500E-01

IS= 7.873E-11
 UA= 6.000E+01
 NE= 3.000E+00
 TF= 3.500E-10
 PE= 4.900E-01
 MC= 3.300E-01

RB= 3.000E+02
 UB= 2.000E+01
 IKR= 1.000E-02
 TR= 5.200E-07
 ME= 2.600E-01
 EG= 1.110E+00

RP4 PNP
 BF= 1.950E+02
 RC= 5.200E+02
 IK= 2.000E-01
 C4= 4.101E+01
 CCS= 4.400E-13
 CJC= 2.500E-12

BR= 1.062E+01
 RE= 0.000E+00
 C2= 1.789E+00
 NC= 1.450E+00
 CJE= 3.700E-12
 PC= 1.500E-01

IS= 3.149E-10
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 4.900E-01
 MC= 3.300E-01

RB= 9.000E+01
 UB= 2.000E+01
 IKR= 4.000E-02
 TR= 5.200E-07
 ME= 2.600E-01
 EG= 1.110E+00

RP8C PNP
 BF= 1.950E+02
 RC= 2.320E+02
 IK= 4.000E-01
 C4= 4.101E+01
 CCS= 1.200E-12
 CJC= 4.000E-12

BR= 1.062E+01
 RE= 0.000E+00
 C2= 1.789E+00
 NC= 1.450E+00
 CJE= 7.300E-12
 PC= 1.500E-01

IS= 6.299E-10
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 4.900E-01
 MC= 3.300E-01

RB= 4.440E+01
 UB= 2.000E+01
 IKR= 8.000E-02
 TR= 5.200E-07
 ME= 2.600E-01
 EG= 1.110E+00

----- ZENER DIODE MODEL -----

NAME

DZR

IS= 5.624E-11
 CJO= 4.500E-13
 PT= 3.000E+00
 BV= 6.460E+00

RS= 7.500E+01
 PB= 6.400E-01
 KF= 0.000E+00
 IBV= 5.000E-04

N= 1.000E+00
 M= 3.700E-01
 AF= 1.000E+00

TT= 1.400E-10
 EQ= 1.110E+00
 FC= 5.000E-01

(TEMPERATURE -55 DEGREES C)

----- BJT MODELS -----				
NAME	TYPE			
RN1LC NPN				
BF=	1.600E+02	BR=	4.590E+00	IS=
RC=	2.424E+02	RE=	0.000E+00	VA=
IK=	5.000E-02	C2=	2.484E+06	NE=
C4=	1.406E+04	NC=	1.450E+00	TF=
CCS=	4.500E-13	CJE=	8.200E-13	PE=
CJC=	8.000E-13	PC=	6.300E-01	MC=
				RB=
				UB=
				IKR=
				TR=
				ME=
				EG=
RP1LC PNP				
BF=	8.025E+01	BR=	5.400E+00	IS=
RC=	3.000E+02	RE=	0.000E+00	VA=
IK=	5.000E-02	C2=	2.484E+06	NE=
C4=	1.406E+04	NC=	1.450E+00	TF=
CCS=	4.500E-13	CJE=	9.500E-13	PE=
CJC=	8.600E-13	PC=	5.100E-01	MC=
				RB=
				UB=
				IKR=
				TR=
				ME=
				EG=
RN0 NPN				
BF=	1.600E+02	BR=	4.590E+00	IS=
RC=	6.318E+02	RE=	0.000E+00	VA=
IK=	2.500E-02	C2=	2.484E+06	NE=
C4=	1.406E+04	NC=	1.450E+00	TF=
CCS=	2.000E-13	CJE=	4.500E-13	PE=
CJC=	5.400E-13	PC=	6.300E-01	MC=
				RB=
				UB=
				IKR=
				TR=
				ME=
				EG=

RN1 NPN
BF= 1.600E+02
RC= 4.146E+02
IK= 5.000E-02
C4= 1.406E+04
CCS= 2.500E-13
CJC= 8.000E-13

BR= 4.590E+00
RE= 0.000E+00
C2= 2.484E+06
MC= 1.450E+00
CJE= 8.200E-13
PC= 6.300E-01

IS= 5.835E-23
VA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 1.000E+00
MC= 2.100E-01

RB= 2.688E+02
UB= 2.000E+01
IKR= 1.000E-02
TR= 4.300E-08
ME= 3.700E-01
EG= 1.110E+00

RN4 NPN
BF= 1.600E+02
RC= 1.050E+02
IK= 2.000E-01
C4= 1.406E+04
CCS= 4.400E-13
CJC= 2.300E-12

BR= 4.590E+00
RE= 0.000E+00
C2= 2.484E+06
MC= 1.450E+00
CJE= 3.200E-12
PC= 6.300E-01

IS= 2.334E-22
VA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 1.000E+00
MC= 2.100E-01

RB= 1.336E+02
UB= 2.000E+01
IKR= 4.000E-02
TR= 4.300E-08
ME= 3.700E-01
EG= 1.110E+00

RN8C NPN
BF= 1.600E+02
RC= 4.800E+01
IK= 4.000E-01
C4= 1.406E+04
CCS= 1.200E-12
CJC= 3.800E-12

BR= 4.590E+00
RE= 0.000E+00
C2= 2.484E+06
MC= 1.450E+00
CJE= 6.200E-12
PC= 6.300E-01

IS= 4.668E-22
VA= 7.500E+01
NE= 2.000E+00
TF= 1.400E-10
PE= 1.000E+00
MC= 2.100E-01

RB= 7.980E+01
UB= 2.000E+01
IKR= 8.000E-02
TR= 4.300E-08
ME= 3.700E-01
EG= 1.110E+00

RP0 PNP
BF= 8.025E+01
RC= 8.568E+02
IK= 2.500E-02
C4= 1.406E+04
CCS= 2.000E-13
CJC= 6.000E-13

BR= 5.400E+00
RE= 0.000E+00
C2= 2.484E+06
MC= 1.450E+00
CJE= 5.200E-13
PC= 5.100E-01

IS= 2.042E-23
VA= 6.000E+01
NE= 2.000E+00
TF= 3.500E-10
PE= 8.500E-01
MC= 3.300E-01

RB= 2.520E+02
UB= 2.000E+01
IKR= 5.000E-03
TR= 3.040E-07
ME= 2.600E-01
EG= 1.110E+00

PNP
 RP1 BF= 8.025E+01
 RC= 8.240E+02
 IK= 5.000E-02
 C4= 1.406E+04
 CCS= 1.250E-13
 CJC= 8.600E-13
 BR= 5.400E+00
 RE= 0.000E+00
 C2= 2.484E+06
 NC= 1.450E+00
 CJE= 9.500E-13
 PC= 5.100E-01
 IS= 4.004E-23
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 8.500E-01
 MC= 3.300E-01
 RB= 2.100E+02
 UB= 2.000E+01
 IKR= 1.000E-02
 TR= 3.040E-07
 ME= 2.600E-01
 EG= 1.110E+00

PNP
 RP4 BF= 8.025E+01
 RC= 1.560E+02
 IK= 2.000E-01
 C4= 1.406E+04
 CCS= 4.400E-13
 CJC= 2.500E-12
 BR= 5.400E+00
 RE= 0.000E+00
 C2= 2.484E+06
 NC= 1.450E+00
 CJE= 3.700E-12
 PC= 5.100E-01
 IS= 1.634E-22
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 8.500E-01
 MC= 3.300E-01
 RB= 6.300E+01
 UB= 2.000E+01
 IKR= 4.000E-02
 TR= 3.040E-07
 ME= 2.600E-01
 EG= 1.110E+00

PNP
 RP8C BF= 8.025E+01
 RC= 6.960E+01
 IK= 4.000E-01
 C4= 1.406E+04
 CCS= 1.200E-12
 CJC= 4.000E-12
 BR= 5.400E+00
 RE= 0.000E+00
 C2= 2.484E+06
 NC= 1.450E+00
 CJE= 7.300E-12
 PC= 5.100E-01
 IS= 3.267E-22
 UA= 6.000E+01
 NE= 2.000E+00
 TF= 3.500E-10
 PE= 8.500E-01
 MC= 3.300E-01
 RB= 3.108E+01
 UB= 2.000E+01
 IKR= 8.000E-02
 TR= 3.040E-07
 ME= 2.600E-01
 EG= 1.110E+00

----- ZENER DIODE MODEL -----

NAME
 DZR
 IS= 2.917E-23
 CJO= 4.500E-13
 PT= 3.000E+00
 BV= 5.992E+00
 RS= 7.500E+01
 PB= 1.000E+00
 KF= 0.000E+00
 IBV= 5.000E-04
 TT= 1.400E-10
 EQ= 1.110E+00
 FC= 5.000E-01

POST-RADIATION GUMMEL-POON MODEL PARAMETERS FOR SPICE II CIRCUIT
SIMULATION OF THE DINS PHOTOPREAMPLIFIER (TEMPERATURE 25 DEGREES C)

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----- BJT MODELS -----
NAME      TYPE

RN1LC     NPN
BF= 4.200E+01
RC= 1.616E+03
IK= 5.948E-02
C4= 4.520E+02
CCS= 4.500E-13
CJC= 8.000E-13

BR= 9.000E+00
RE= 0.000E+00
C2= 9.029E+01
NC= 1.450E+00
CJE= 8.200E-13
PC= 4.700E-01

IS= 1.000E-15
QA= 7.500E+01
NE= 1.448E+00
TF= 1.400E-10
PE= 8.400E-01
MC= 2.100E-01

RB= 3.200E+02
UB= 2.000E+01
IKR= 1.000E-02
TR= 7.500E-08
ME= 3.700E-01
EG= 1.110E+00

RP1LC     PNP
BF= 2.055E+01
RC= 7.500E+02
IK= 6.217E-02
C4= 4.520E+02
CCS= 4.500E-13
CJC= 8.600E-13

BR= 9.000E+00
RE= 0.000E+00
C2= 8.374E+01
NC= 1.450E+00
CJE= 9.500E-13
PC= 3.500E-01

IS= 7.000E-16
QA= 6.000E+01
NE= 1.381E+00
TF= 3.500E-10
PE= 6.900E-01
MC= 3.300E-01

RB= 2.500E+02
UB= 2.000E+01
IKR= 1.000E-02
TR= 4.000E-07
ME= 2.600E-01
EG= 1.110E+00

RN0       NPN
BF= 4.200E+01
RC= 4.212E+03
IK= 2.974E-02
C4= 4.520E+02
CCS= 2.000E-13
CJC= 5.400E-13

BR= 9.000E+00
RE= 0.000E+00
C2= 9.029E+01
NC= 1.450E+00
CJE= 4.500E-13
PC= 4.700E-01

IS= 5.000E-16
QA= 7.500E+01
NE= 1.448E+00
TF= 1.400E-10
PE= 8.400E-01
MC= 2.100E-01

RB= 3.890E+02
UB= 2.000E+01
IKR= 5.000E-03
TR= 7.500E-08
ME= 3.700E-01
EG= 1.110E+00

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RN1	NPN	BR= 9.000E+00	IS= 1.000E-15	RB= 3.200E+02
BF= 4.200E+01		RE= 0.000E+00	UA= 7.500E+01	UB= 2.000E+01
RC= 3.764E+03		C2= 9.029E+01	NE= 1.448E+00	IKR= 1.000E-02
IK= 2.5948E-02		NC= 1.450E+00	TF= 1.400E-10	TR= 7.500E-08
C4= 4.520E+02		CJE= 8.200E-13	PE= 8.400E-01	ME= 3.700E-01
CCS= 3.500E-13		PC= 4.700E-01	MC= 2.100E-01	EG= 1.110E+00
CJC= 8.000E-13				
RN4	NPN	BR= 9.000E+00	IS= 4.000E-15	RB= 1.590E+02
BF= 4.200E+01		RE= 0.000E+00	UA= 7.500E+01	UB= 2.000E+01
RC= 7.000E+02		C2= 9.029E+01	NE= 1.448E+00	IKR= 4.000E-02
IK= 2.379E-01		NC= 1.450E+00	TF= 1.400E-10	TR= 7.500E-08
C4= 4.520E+02		CJE= 3.200E-12	PE= 8.400E-01	ME= 3.700E-01
CCS= 4.400E-13		PC= 4.700E-01	MC= 2.100E-01	EG= 1.110E+00
CJC= 2.300E-12				
RN8C	NPN	BR= 9.000E+00	IS= 8.000E-15	RB= 9.500E+01
BF= 4.200E+01		RE= 0.000E+00	UA= 7.500E+01	UB= 2.000E+01
RC= 3.200E+02		C2= 9.029E+01	NE= 1.448E+00	IKR= 8.000E-02
IK= 4.758E-01		NC= 1.450E+00	TF= 1.400E-10	TR= 7.500E-08
C4= 4.520E+02		CJE= 6.200E-12	PE= 8.400E-01	ME= 3.700E-01
CCS= 1.200E-12		PC= 4.700E-01	MC= 2.100E-01	EG= 1.110E+00
CJC= 3.800E-12				
RP0	PNP	BR= 9.000E+00	IS= 3.500E-16	RB= 3.000E+02
BF= 2.055E+01		RE= 0.000E+00	UA= 6.000E+01	UB= 2.000E+01
RC= 2.142E+03		C2= 8.374E+01	NE= 1.381E+00	IKR= 5.000E-03
IK= 3.109E-02		NC= 1.450E+00	TF= 3.500E-10	TR= 4.000E-07
C4= 4.520E+02		CJE= 5.200E-13	PE= 6.900E-01	ME= 2.600E-01
CCS= 2.000E-13		PC= 3.500E-01	MC= 3.300E-01	EG= 1.110E+00
CJC= 6.000E-13				

PNP
 RP1
 BF= 2.055E+01
 RC= 1.560E+03
 IK= 6.217E-02
 C4= 4.520E+02
 CCS= 2.500E-13
 CJC= 8.600E-13
 BR= 9.000E+00
 RE= 0.000E+00
 C2= 8.374E+01
 NC= 1.450E+00
 CJE= 9.500E-13
 PC= 3.500E-01
 IS= 7.000E-16
 UA= 6.000E+01
 NE= 1.381E+00
 TF= 3.500E-10
 PE= 6.900E-01
 MC= 3.300E-01
 RB= 2.500E+02
 UB= 2.000E+01
 IKR= 1.000E-02
 TR= 4.000E-07
 ME= 2.600E-01
 EG= 1.110E+00

PNP
 RP4
 BF= 2.055E+01
 RC= 3.900E+02
 IK= 2.487E-01
 C4= 4.520E+02
 CCS= 4.400E-13
 CJC= 2.500E-12
 BR= 9.000E+00
 RE= 0.000E+00
 C2= 8.374E+01
 NC= 1.450E+00
 CJE= 3.700E-12
 PC= 3.500E-01
 IS= 2.800E-15
 UA= 6.000E+01
 NE= 1.381E+00
 TF= 3.500E-10
 PE= 6.900E-01
 MC= 3.300E-01
 RB= 7.500E+01
 UB= 2.000E+01
 IKR= 4.000E-02
 TR= 4.000E-07
 ME= 2.600E-01
 EG= 1.110E+00

PNP
 RP8C
 BF= 2.055E+01
 RC= 1.740E+02
 IK= 4.974E-01
 C4= 4.520E+02
 CCS= 1.200E-12
 CJC= 4.000E-12
 BR= 9.000E+00
 RE= 0.000E+00
 C2= 8.374E+01
 NC= 1.450E+00
 CJE= 7.300E-12
 PC= 3.500E-01
 IS= 5.600E-15
 UA= 6.000E+01
 NE= 1.381E+00
 TF= 3.500E-10
 PE= 6.900E-01
 MC= 3.300E-01
 RB= 3.700E+01
 UB= 2.000E+01
 IKR= 8.000E-02
 TR= 4.000E-07
 ME= 2.600E-01
 EG= 1.110E+00

----- ZENER DIODE MODEL -----

NAME
 DZR
 IS= 5.000E-16
 CJO= 4.500E-13
 PT= 3.000E+00
 BV= 6.200E+00
 RS= 7.500E+01
 PE= 8.400E-01
 KF= 0.000E+00
 IBV= 5.000E-04
 N= 1.000E+00
 M= 3.700E-01
 AF= 1.000E+00
 TT= 1.400E-10
 EQ= 1.110E+00
 FC= 5.000E-01

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APPENDIX 2.0

DC CIRCUIT SIMULATIONS

- 2.1 25° Operating Points
- 2.2 125° " "
- 2.3 -55° " "
- 2.4 25° Post Neutron Operating Points

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1 DINS PHOTOPREAMPLIFIER OPERATING POINTS (TEMPERATURE 25 DEGREES C)
2
3
4 ----- VOLTAGE SUPPLY CURRENTS -----
5
6 NAME      CURRNT      NAME      CURRNT
7 VPOS      -3.299E-07 VNEG      3.754E-03    TOTAL POWER = 106 MW (ONE CHANNE
8
9
10 ----- ZENER DIODE -----
11
12 NAME: 0Z1      MODEL: DZR
13
14 ID=-2.761E-04    VD=-6.205F+00    REG= 9.305E+01    CAP= 1.710E-1
15
16 ----- BJT'S -----
17
18 NAME: Q1      MODEL: RP0
19
20 IB=-4.831E-07    IC=-6.936F-05    VBF=-6.645E-01    VRC= 1.222E+0
21 VCE=-1.288E+01  BETA DC= 1.436E+02    GM= 2.689E-03    RPI= 5.841E+0
22 RO= 1.011E+06    CPI= 1.583E-12    CMU= 1.845E-13  BETA AC= 1.571E+0
23 FT= 2.422E+08
24
25 NAME: Q2      MODEL: RP0
26
27 IB=-4.826E-07    IC=-6.935F-05    VBF=-6.645E-01    VRC= 1.229E+0
28 VCE=-1.295E+01  BETA DC= 1.437E+02    GM= 2.689E-03    RPI= 5.847E+0
29 RO= 1.012E+06    CPI= 1.582E-12    CMU= 1.842E-13  BETA AC= 1.572E+0
30 FT= 2.423E+08
31
32 NAME: Q3      MODEL: RN0
33
34 IB= 3.042E-07    IC= 4.917E-05    VBF= 6.471E-01    VRC=-1.295E+0
35 VCE= 1.360E+01  BETA DC= 1.616E+02    GM= 1.908E-03    RPI= 9.873E+0
36 RO= 1.738E+06    CPI= 9.334E-13    CMU= 2.673E-13  BETA AC= 1.884E+0
37 FT= 2.529E+08
38
39 NAME: Q4      MODEL: RN1
40
41 IB= 5.137E-07    IC= 6.907E-05    VBF= 6.420E-01    VRC=-7.156E-0
42 VCE= 1.358E+00  BETA DC= 1.345E+02    GM= 2.640E-03    RPI= 5.922E+0
43 RO= 1.061E+06    CPI= 1.653E-12    CMU= 6.644E-13  BETA AC= 1.587E+0
44 FT= 1.841E+08
45
46 NAME: Q5      MODEL: RN1
47
48 IB= 5.140E-07    IC= 6.905E-05    VBF= 6.420F-01    VRC=-6.471E-0
49 VCE= 1.289E+00  BETA DC= 1.343F+02    GM= 2.679E-03    RPI= 5.918F+0
50 RO= 1.060E+06    CPI= 1.653F-12    CMU= 6.731F-13  BETA AC= 1.586E+0
51 FT= 1.833E+08
52
53 NAME: Q6      MODEL: RN1
54
55 IB= 2.192E-07    IC= 2.423F-05    VBF= 6.151E-01    VRC=-3.142E-0

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```

56      VCE= 9.293E-01 BETAOC= 1.105E+02      GM= 9.409E-04      RPI= 1.495E+
57      RO= 3.013E+06      CPI= 1.378E-12      CMU= 7.217E-13 BETAAC= 1.406E+
58      FT= 7.133E+07
59
60 NAME: Q7      MODEL: RN1
61
62      IB= 2.192E-07      IC= 2.423E-05      VBE= 6.151E-01      VBC=-3.142E-
63      VCE= 9.293E-01 BETAOC= 1.105E+02      GM= 9.409E-04      RPI= 1.495E+
64      RO= 3.013E+06      CPI= 1.378E-12      CMU= 7.217E-13 BETAAC= 1.406E+
65      FT= 7.133E+07
66
67 NAME: Q8      MODEL: RPO
68
69      IB=-9.047E-07      IC=-1.397E-04      VBE=-6.821E-01      VBC= 1.392E+
70      VCE=-1.461E+01 BETAOC= 1.544E+02      GM= 5.404E-03      RPI= 3.044E+
71      RO= 5.132E+05      CPI= 2.381E-12      CMU= 1.773E-13 BETAAC= 1.645E+
72      FT= 3.362E+08
73
74 NAME: Q9      MODEL: RPI
75
76      IB=-2.244E-06      IC=-2.855E-04      VBE=-6.883E-01      VBC= 6.424E-
77      VCE=-1.331E+00 BETAOC= 1.272E+02      GM= 1.103E-02      RPI= 1.219E+
78      RO= 2.042E+05      CPI= 5.459E-12      CMU= 6.855E-13 BETAAC= 1.344E+
79      FT= 2.857E+08
80
81 NAME: Q10     MODEL: RPI
82
83      IB=-4.478E-07      IC=-5.971E-05      VBE=-6.424E-01      VBC= 1.328E+
84      VCE=-1.392E+01 BETAOC= 1.343E+02      GM= 2.318E-03      RPI= 6.560E+
85      RO= 1.194E+06      CPI= 2.078E-12      CMU= 2.572E-13 BETAAC= 1.521E+
86      FT= 1.580E+08
87
88 NAME: Q11     MODEL: RNO
89
90      IB= 1.381E-06      IC= 2.859E-04      VBE= 6.910E-01      VBC=-1.998E+
91      VCE= 2.067E+01 BETAOC= 2.071E+02      GM= 1.101E-02      RPI= 2.010E+
92      RO= 3.221E+05      CPI= 2.001E-12      CMU= 2.453E-13 BETAAC= 2.214E+
93      FT= 7.803E+08
94
95 NAME: Q12     MODEL: RNO
96
97      IB= 2.961E-07      IC= 4.760E-05      VBE= 6.463E-01      VBC=-1.288E-
98      VCE= 1.353E+01 BETAOC= 1.608E+02      GM= 1.847E-03      RPI= 1.017E-
99      RO= 1.794E+06      CPI= 9.256E-13      CMU= 2.676E-13 BETAAC= 1.877E-
100     FT= 2.463E+08
101
102 NAME: Q13     MODEL: RN1
103
104      IB= 3.705E-07      IC= 4.652E-05      VBE= 6.319E-01      VBC=-3.835E-
105     VCE= 1.015E+00 BETAOC= 1.256E+02      GM= 1.806E-03      RPI= 8.428E-
106     RO= 1.569E+06      CPI= 1.518E-12      CMU= 7.115E-13 BETAAC= 1.522E-
107     FT= 1.289E+04
108
109 NAME: Q14     MODEL: RN1
110

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111 IB= 1.812E-06 IC= 2.869E-04 VBE= 6.793E-01 VBC=-6.337E-01
112 VCE= 1.313E+00 BETAOC= 1.584E+02 GM= 1.108E-02 RPI= 1.559E+01
113 RO= 2.540E+05 CPI= 2.919E-12 CMU= 6.970E-13 BETAAC= 1.728E+01
114 FT= 4.878E+08
115
116 NAME: Q15 MODEL: RP0
117
118 IB=-1.573E-06 IC=-2.474E-04 VBE=-6.974E-01 VBC= 1.325E+01
119 VCE=-1.395E+01 BETAOC= 1.573E+02 GM= 9.538E-03 RPI= 1.723E+01
120 RO= 2.862E+05 CPI= 3.668E-12 CMU= 1.809E-13 BETAAC= 1.643E+01
121 FT= 3.944E+08
122
123 NAME: Q16 MODEL: RN1LC
124
125 IB= 1.566E-06 IC= 2.428E-04 VBE= 6.751E-01 VBC= 0.000E+01
126 VCE= 6.751E+01 BETAOC= 1.550E+02 GM= 9.387E-03 RPI= 1.815E+01
127 RO= 2.981E+05 CPI= 2.675E-12 CMU= 8.401E-13 BETAAC= 1.704E+01
128 FT= 4.250E+08
129
130 NAME: Q17 MODEL: RP1LC
131
132 IB=-1.938E-06 IC=-2.424E-04 VBE=-6.842E-01 VBC= 0.000E+01
133 VCE=-6.842E-01 BETAOC= 1.251E+02 GM= 9.372E-03 RPI= 1.418E+01
134 RO= 2.385E+05 CPI= 4.872E-12 CMU= 9.888E-13 BETAAC= 1.329E+01
135 FT= 2.545E+08
136
137 NAME: Q18 MODEL: RN1
138
139 IB= 3.919E-07 IC= 5.860E-05 VBE= 6.337E-01 VBC=-1.328E+01
140 VCE= 1.391E+01 BETAOC= 1.495E+02 GM= 2.275E-03 RPI= 7.927E+01
141 RO= 1.465E+06 CPI= 1.538E-12 CMU= 3.940E-13 BETAAC= 1.804E+01
142 FT= 1.874E+08
143
144 NAME: Q19 MODEL: RN1
145
146 IB= 1.377E-06 IC= 2.479E-04 VBE= 6.714E-01 VBC=-1.285E+01
147 VCE= 1.352E+01 BETAOC= 1.800E+02 GM= 9.595E-03 RPI= 2.077E+01
148 RO= 3.435E+05 CPI= 2.489E-12 CMU= 3.975E-13 BETAAC= 1.993E+01
149 FT= 5.290E+08
150
151 NAME: Q20 MODEL: RN1LC
152
153 IB= 1.595E-06 IC= 2.477E-04 VBE= 6.756E-01 VBC= 0.000E+01
154 VCE= 6.756E-01 BETAOC= 1.553E+02 GM= 9.577E-03 RPI= 1.781E+01
155 RO= 2.921E+05 CPI= 2.704E-12 CMU= 8.410E-13 BETAAC= 1.706E+01
156 FT= 4.299E+08
157
158 NAME: Q21 MODEL: RN4
159
160 IB= 3.083E-06 IC= 5.249E-04 VBE= 6.545E-01 VBC=-1.430E+01
161 VCE= 1.495E+01 BETAOC= 1.703E+02 GM= 2.036E-02 RPI= 9.591E+01
162 RO= 1.653E+05 CPI= 7.467E-12 CMU= 1.117E-12 BETAAC= 1.952E+01
163 FT= 3.775E+08
164
165 NAME: Q22 MODEL: RP4


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166
167      IB=-3.5A1E-06      IC=-5.253E-04      VBF=-6.625E-01      VBC= 1.429E+0
168      VCE=-1.495E+01 BETAOC= 1.467E+02      GM= 2.037E-02      RPI= 7.906E+0
169      RO= 1.374E+05      CPI= 1.145E-11      CMU= 7.315E-13 BETAAC= 1.610E+0
170      FT= 2.661E+08
171
172 NAME: Q23      MODEL: RNILC
173
174      IB= 5.178E-07      IC= 6.906E-05      VBE= 6.423E-01      VBC= 0.000E+0
175      VCE= 6.423E-01 BETAOC= 1.334E+02      GM= 2.680E-03      RPI= 5.871E+0
176      RO= 1.051E+06      CPI= 1.657E-12      CMU= 8.103E-13 BETAAC= 1.573E+0
177      FT= 1.729E+08
178
179 NAME: Q24      MODEL: RNILC
180
181      IB= 5.177E-07      IC= 6.905E-05      VBE= 6.423E-01      VBC= 0.000E+0
182      VCE= 6.423E-01 BETAOC= 1.334E+02      GM= 2.679E-03      RPI= 5.872E+0
183      RO= 1.051E+06      CPI= 1.657E-12      CMU= 8.103E-13 BETAAC= 1.573E+0
184      FT= 1.729E+08
185
186 NAME: Q25      MODEL: RNILC
187
188      IB= 4.287E-07      IC= 5.518E-05      VBE= 6.365E-01      VBC= 0.000E+0
189      VCE= 6.365E-01 BETAOC= 1.297E+02      GM= 2.142E-03      RPI= 7.195E+0
190      RO= 1.315E+06      CPI= 1.573E-12      CMU= 8.082E-13 BETAAC= 1.541E+0
191      FT= 1.432E+08
192
193 NAME: Q26      MODEL: RPILC
194
195      IB=-4.9A8E-07      IC=-5.494E-05      VBE=-6.455E-01      VBC= 0.000E+0
196      VCE=-6.455E-01 BETAOC= 1.101E+02      GM= 2.132E-03      RPI= 5.853E+0
197      RO= 1.056E+06      CPI= 2.170E-12      CMU= 8.834E-13 BETAAC= 1.248E+0
198      FT= 1.111E+08
199
200 NAME: Q27      MODEL: RNILC
201
202      IB= 1.751E-06      IC= 2.744E-04      VBE= 6.7A3E-01      VBC= 0.000E+0
203      VCE= 6.7A3E-01 BETAOC= 1.567E+02      GM= 1.060E-02      RPI= 1.615E+0
204      RO= 2.637E+05      CPI= 2.859E-12      CMU= 8.462E-13 BETAAC= 1.712E+0
205      FT= 4.554E+08
206
207 NAME: Q28      MODEL: RNILC
208
209      IB= 1.751E-06      IC= 2.744E-04      VBE= 6.7A3E-01      VBC= 0.000E+0
210      VCE= 6.7A3E-01 BETAOC= 1.567E+02      GM= 1.060E-02      RPI= 1.615E+0
211      RO= 2.637E+05      CPI= 2.859E-12      CMU= 8.462E-13 BETAAC= 1.712E+0
212      FT= 4.554E+08
213
214 NAME: Q29      MODEL: RNILC
215
216      IB= 1.751E-06      IC= 2.744E-04      VBE= 6.7A3E-01      VBC= 0.000E+0
217      VCE= 6.7A3E-01 BETAOC= 1.567E+02      GM= 1.060E-02      RPI= 1.615E+0
218      RO= 2.637E+05      CPI= 2.859E-12      CMU= 8.462E-13 BETAAC= 1.712E+0
219      FT= 4.554E+08
220

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221 NAME: Q30 MODEL: RNO
222
223 IB=-7.403E-11 IC= 7.431E-11 VHF= 0.000E+00 VBC=-1.220E+
224 VCE= 1.220E+01 BETAOC=-1.004E+00 GM=-1.504E-14 RPI= 1.713E+
225 RO= 3.877E+13 CPI= 4.500E-13 CMU= 2.704E-13 BETAAC=-2.575E-
226 FT=-3.322E-03
227
228 NAME: Q31 MODEL: RNO
229
230 IB= 3.689E-07 IC= 6.291E-05 VBE= 6.529E-01 VBC=-1.497E+
231 VCE= 1.562E+01 BETAOC= 1.705E+02 GM= 2.440E-03 RPI= 8.038E+
232 RO= 1.390E+06 CPI= 9.954E-13 CMU= 2.596E-13 BETAAC= 1.961E+
233 FT= 3.094E+08
234
235 NAME: Q32 MODEL: RNO
236
237 IB= 3.689E-07 IC= 6.291E-05 VBE= 6.529E-01 VBC=-1.497E+
238 VCE= 1.562E+01 BETAOC= 1.705E+02 GM= 2.440E-03 RPI= 8.037E+
239 RO= 1.390E+06 CPI= 9.954E-13 CMU= 2.596E-13 BETAAC= 1.961E+
240 FT= 3.094E+08
241
242 NAME: Q33 MODEL: RNO
243
244 IB= 3.797E-07 IC= 6.376E-05 VBE= 6.537E-01 VBC=-1.325E+
245 VCE= 1.390E+01 BETAOC= 1.679E+02 GM= 2.473E-03 RPI= 7.793E+
246 RO= 1.345E+06 CPI= 1.006E-12 CMU= 2.662E-13 BETAAC= 1.927E+
247 FT= 3.094E+08
248
249 NAME: Q34 MODEL: RNO
250
251 IB= 3.797E-07 IC= 6.376E-05 VBE= 6.537E-01 VBC=-1.325E+
252 VCE= 1.390E+01 BETAOC= 1.679E+02 GM= 2.473E-03 RPI= 7.793E+
253 RO= 1.345E+06 CPI= 1.006E-12 CMU= 2.662E-13 BETAAC= 1.927E+
254 FT= 3.094E+08
255
256 NAME: Q35 MODEL: RPO
257
258 IB= 4.391E-12 IC=-4.405E-12 VBE= 0.000E+00 VBC= 1.034E+
259 VCE=-1.034E+00 BETAOC=-1.003E+00 GM=-9.387E-16 RPI= 2.447E+
260 RO= 7.096E+13 CPI= 5.200E-13 CMU= 3.812E-13 BETAAC=-2.297E-
261 FT=-1.658E-04
262
263 NAME: Q36 MODEL: RPI
264
265 IB= 8.782E-12 IC=-8.810E-12 VBE= 0.000E+00 VBC= 1.034E+
266 VCF=-1.034E+00 BETAOC=-1.003E+00 GM=-1.877E-15 RPI= 1.223E+
267 RO= 3.548E+13 CPI= 9.500E-13 CMU= 5.464E-13 BETAAC=-2.297E-
268 FT=-1.997E-04
269
270 NAME: Q37 MODEL: RPO
271
272 IB= 4.391E-12 IC=-4.405E-12 VBE= 0.000E+00 VBC= 1.034E+
273 VCE=-1.034E+00 BETAOC=-1.003E+00 GM=-9.387E-16 RPI= 2.447E+
274 RO= 7.096E+13 CPI= 5.200E-13 CMU= 3.812E-13 BETAAC=-2.297E-
275 FT=-1.658E-04

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276
277 NAME: Q38 MODEL: RN1
278
279 IR=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
280 VCE= 1.026E+00 BETAOC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
281 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
282 FT=-2.781E-04
283
284 NAME: Q39 MODEL: RN1
285
286 IR=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
287 VCE= 1.026E+00 BETAOC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
288 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
289 FT=-2.781E-04
290
291 NAME: Q40 MODEL: RN1
292
293 IR=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
294 VCE= 1.026E+00 BETAOC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
295 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
296 FT=-2.781E-04
297
298 NAME: Q41 MODEL: RN1
299
300 IR=-1.245E-11 IC= 1.249E-11 VBF= 0.000E+00 VBC=-1.026E+0
301 VCE= 1.026E+00 BETAOC=-1.003E+00 GM=-2.529E-15 RPI= 8.564E+1
302 RO= 2.501E+13 CPI= 8.200E-13 CMU= 6.273E-13 BETAAC=-2.165E-0
303 FT=-2.781E-04
304
305 NAME: Q42 MODEL: RP0
306
307 IB= 6.346E-11 IC=-6.372E-11 VBF= 0.000E+00 VBC= 1.494E+0
308 VCE=-1.494E+01 BETAOC=-1.004E+00 GM=-1.357E-14 RPI= 2.447E+1
309 RO= 4.900E+13 CPI= 5.200E-13 CMU= 1.725E-13 BETAAC=-3.320E-0
310 FT=-3.118E-03
311
312 NAME: Q43 MODEL: RN4
313
314 IB=-6.599E-11 IC= 6.621E-11 VBF= 0.000E+00 VBC=-1.359E+0
315 VCE= 1.359E+00 BETAOC=-1.003E+00 GM=-1.340E-14 RPI= 2.141E+1
316 RO= 6.198E+12 CPI= 3.200E-12 CMU= 1.729E-12 BETAAC=-2.870E-0
317 FT=-4.328E-04
318
319 NAME: Q44 MODEL: RN0
320
321 IR=-1.247E-11 IC= 1.252E-11 VBF= 0.000E+00 VBC=-2.056E+0
322 VCE= 2.056E+00 BETAOC=-1.003E+00 GM=-2.534E-15 RPI= 1.713E+1
323 RO= 4.871E+13 CPI= 4.500E-13 CMU= 3.793E-13 BETAAC=-4.339E-0
324 FT=-4.862E-04
325
326 NAME: Q45 MODEL: PN0
327
328 IR=-6.225E-12 IC= 6.245E-12 VBF= 0.000E+00 VBC=-1.026E+0
329 VCE= 1.026E+00 BETAOC=-1.003E+00 GM=-1.264E-15 RPI= 1.713E+1
330 RO= 5.002E+13 CPI= 4.500E-13 CMU= 4.235E-13 BETAAC=-2.165E-0

```

331 FT=-2.304E-04

332

333 NAME: Q46 MODEL: RNO

334

335 IB=-6.225E-12 IC= 6.245E-12 VBE= 0.000E+00 VBC=-1.024E+0

336 VCE= 1.026E+00 BETAOC=-1.003E+00 GM=-1.264E-15 RPI= 1.713E+

337 RO= 5.002E+13 CPI= 4.500E-13 CMU= 4.235E-13 BETAAC=-2.165E-

338 FT=-2.304E-04

339

340 NAME: Q47 MODEL: RPO

341

342 IB=-1.215E-06 IC=-1.879E-04 VBE=-6.903E-01 VBC= 1.282E+

343 VCE=-1.351E+01 BETAOC= 1.546E+02 GM= 7.256E-03 RPI= 2.245E+

344 RO= 3.752E+05 CPI= 2.977E-12 CMU= 1.824E-13 BETAAC= 1.629E+

345 FT= 3.655E+08

346

347 NAME: Q48 MODEL: RPO

348

349 IB=-1.216E-06 IC=-1.879E-04 VBE=-6.903E-01 VBC= 1.281E+

350 VCE=-1.350E+01 BETAOC= 1.545E+02 GM= 7.256E-03 RPI= 2.245E+

351 RO= 3.750E+05 CPI= 2.978E-12 CMU= 1.825E-13 BETAAC= 1.629E+

352 FT= 3.654E+08

353

354 NAME: Q49 MODEL: RNO

355

356 IB= 3.124E-07 IC= 5.063E-05 VBE= 6.479E-01 VBC=-1.281E+

357 VCE= 1.345E+01 BETAOC= 1.621E+02 GM= 1.964E-03 RPI= 9.597E+

358 RO= 1.685E+06 CPI= 9.412E-13 CMU= 2.680E-13 BETAAC= 1.885E+

359 FT= 2.5A6E+08

360

361 NAME: Q50 MODEL: RN1

362

363 IB= 1.231E-06 IC= 1.876E-04 VBE= 6.681E-01 VBC=-6.303E-

364 VCE= 1.298E+00 BETAOC= 1.523E+02 GM= 7.261E-03 RPI= 2.337E+

365 RO= 3.892E+05 CPI= 2.345E-12 CMU= 6.869E-13 BETAAC= 1.697E+

366 FT= 3.811E+08

367

368 NAME: Q51 MODEL: RN1

369

370 IB= 1.231E-06 IC= 1.876E-04 VBE= 6.681E-01 VBC=-6.479E-

371 VCE= 1.316E+00 BETAOC= 1.524E+02 GM= 7.261E-03 RPI= 2.338E+

372 RO= 3.892E+05 CPI= 2.345E-12 CMU= 6.843E-13 BETAAC= 1.697E+

373 FT= 3.815E+08

374

375 NAME: Q52 MODEL: RN1

376

377 IB= 2.191E-07 IC= 2.424E-05 VBE= 6.151E-01 VBC=-4.027E-

378 VCE= 1.018E+00 BETAOC= 1.106E+02 GM= 9.415E-04 RPI= 1.496E+

379 RO= 3.015E+06 CPI= 1.377E-12 CMU= 7.054E-13 BETAAC= 1.408E+

380 FT= 7.194E+07

381

382 NAME: Q53 MODEL: RN1

383

384 IB= 2.191E-07 IC= 2.424E-05 VBE= 6.151E-01 VBC=-4.027E-

385 VCE= 1.018E+00 BETAOC= 1.106E+02 GM= 9.415E-04 RPI= 1.496E+

```

386      RO= 3.015E+06      CPI= 1.377E-12      CMU= 7.054E-13 BETAAC= 1.406E+0
387      FT= 7.194E+07
388
389  NAME:  Q54      MODEL:  RP0
390
391      IR=-2.386E-06      IC=-3.782E-04      VBE=-7.089E-01      VBC= 1.287E+0
392      VCE=-1.358E+01 BETAOC= 1.585E+02      GM= 1.451E-02      RPI= 1.125E+0
393      RO= 1.856E+05      CPI= 5.253E-12      CMU= 1.835E-13 BETAAC= 1.633E+0
394      FT= 4.249E+08
395
396  NAME:  Q55      MODEL:  RP1
397
398      IR=-2.581E-06      IC=-3.308E-04      VBE=-6.922E-01      VBC= 6.510E-0
399      VCE=-1.343E+00 BETAOC= 1.281E+02      GM= 1.276E-02      RPI= 1.055E+0
400      RO= 1.761E+05      CPI= 6.109E-12      CMU= 6.984E-13 BETAAC= 1.347E+0
401      FT= 2.944E+08
402
403  NAME:  Q56      MODEL:  RP1
404
405      IR=-6.019E-07      IC=-8.318E-05      VBE=-6.510E-01      VBC= 1.310E+0
406      VCE=-1.375E+01 BETAOC= 1.382E+02      GM= 3.228E-03      RPI= 4.799E+0
407      RO= 8.544E+05      CPI= 2.358E-12      CMU= 2.585E-13 BETAAC= 1.549E+0
408      FT= 1.964E+08
409
410  NAME:  Q57      MODEL:  RN0
411
412      IR= 1.589E-06      IC= 3.314E-04      VBE= 6.950E-01      VBC=-1.980E+0
413      VCE= 2.049E+01 BETAOC= 2.085E+02      GM= 1.274E-02      RPI= 1.738E+0
414      RO= 2.772E+05      CPI= 2.213E-12      CMU= 2.459E-13 BETAAC= 2.215E+0
415      FT= 8.250E+08
416
417  NAME:  Q58      MODEL:  RN0
418
419      IR= 2.991E-07      IC= 4.814E-05      VBE= 6.466E-01      VBC=-1.282E+0
420      VCE= 1.347E+01 BETAOC= 1.609E+02      GM= 1.868E-03      RPI= 1.005E+0
421      RO= 1.773E+06      CPI= 9.285E-13      CMU= 2.679E-13 BETAAC= 1.878E+0
422      FT= 2.485E+08
423
424  NAME:  Q59      MODEL:  RN1
425
426      IR= 3.722E-07      IC= 4.678E-05      VBE= 6.321E-01      VBC=-3.865E-0
427      VCE= 1.019E+00 BETAOC= 1.257E+02      GM= 1.816E-03      RPI= 8.385E+0
428      RO= 1.560E+06      CPI= 1.520E-12      CMU= 7.110E-13 BETAAC= 1.523E+0
429      FT= 1.246E+08
430
431  NAME:  Q60      MODEL:  RN1
432
433      IR= 2.076E-06      IC= 3.325E-04      VBE= 6.832E-01      VBC=-6.368E-0
434      VCE= 1.320E+00 BETAOC= 1.602E+02      GM= 1.283E-02      RPI= 1.353E+0
435      RO= 2.191E+05      CPI= 3.143E-12      CMU= 7.017E-13 BETAAC= 1.736E+0
436      FT= 5.258E+08
437
438  NAME:  Q61      MODEL:  RP0
439
440      IR=-1.923E-06      IC=-3.039E-04      VBE=-7.029E-01      VBC= 1.307E+0

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441 VCE=-1.377E+01 BETAOC= 1.5A1E+02 GM= 1.149E-02 RPI= 1.402E+0
442 RO= 2.321E+05 CPI= 4.348E-12 CMU= 1.821E-13 BETAAC= 1.640E+0
443 FT= 4.107E+08
444
445 NAME: Q62 MODEL: RN1LC
446
447 IB= 1.883E-06 IC= 2.970E-04 VBE= 6.804E-01 VBC= 0.000E+0
448 VCE= 6.804E-01 BETAOC= 1.577E+02 GM= 1.147E-02 RPI= 1.497E+0
449 RO= 2.435E+05 CPI= 2.991E-12 CMU= 8.508E-13 BETAAC= 1.717E+0
450 FT= 4.752E+08
451
452 NAME: Q63 MODEL: RP1LC
453
454 IB=-2.345E-06 IC=-2.966E-04 VBE=-6.895E-01 VBC= 0.000E+0
455 VCE=-6.895E-01 BETAOC= 1.265E+02 GM= 1.145E-02 RPI= 1.165E+0
456 RO= 1.949E+05 CPI= 5.653E-12 CMU= 1.031E-12 BETAAC= 1.334E+0
457 FT= 2.727E+08
458
459 NAME: Q64 MODEL: RN1
460
461 IB= 4.329E-07 IC= 6.599E-05 VBE= 6.368E-01 VBC=-1.322E+0
462 VCE= 1.386E+01 BETAOC= 1.525E+02 GM= 2.562E-03 RPI= 7.119E+0
463 RO= 1.300E+06 CPI= 1.577E-12 CMU= 3.944E-13 BETAAC= 1.824E+0
464 FT= 2.069E+08
465
466 NAME: Q65 MODEL: RN1
467
468 IB= 1.662E-06 IC= 3.046E-04 VBE= 6.768E-01 VBC=-1.278E+0
469 VCE= 1.346E+01 BETAOC= 1.833E+02 GM= 1.178E-02 RPI= 1.705E+0
470 RO= 2.792E+05 CPI= 2.771E-12 CMU= 3.981E-13 BETAAC= 2.008E+0
471 FT= 5.914E+08
472
473 NAME: Q66 MODEL: RN1LC
474
475 IB= 1.926E-06 IC= 3.044E-04 VBE= 6.810E-01 VBC= 0.000E+0
476 VCE= 6.810E-01 BETAOC= 1.580E+02 GM= 1.175E-02 RPI= 1.462E+0
477 RO= 2.376E+05 CPI= 3.033E-12 CMU= 8.523E-13 BETAAC= 1.718E+0
478 FT= 4.814E+08
479
480 NAME: Q67 MODEL: RN8C
481
482 IB= 4.970E-06 IC= 8.145E-04 VBE= 6.481E-01 VBC=-1.428E+0
483 VCE= 1.493E+01 BETAOC= 1.647E+02 GM= 3.176E-02 RPI= 6.034E+0
484 RO= 1.060E+05 CPI= 1.348E-11 CMU= 1.845E-12 BETAAC= 1.916E+0
485 FT= 3.298E+08
486
487 NAME: Q68 MODEL: RP8C
488
489 IB=-5.708E-06 IC=-8.178E-04 VBE=-6.560E-01 VBC= 1.427E+0
490 VCE=-1.493E+01 BETAOC= 1.433E+02 GM= 3.173E-02 RPI= 5.014E+0
491 RO= 8.829E+04 CPI= 2.006E-11 CMU= 1.170E-12 BETAAC= 1.591E+0
492 FT= 2.379E+08
493
494 NAME: Q69 MODEL: RN1LC
495

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496      IB= 1.240E-06      IC= 1.876E-04      VBE= 6.6A3E-01      VBC= 0.000E+0
497      VCE= 6.6A3E-01      BETADC= 1.513E+02      GM= 7.260E-03      RPI= 2.320E+0
498      RO= 3.861E+05      CPI= 2.354E-12      CMU= 8.299E-13      BETAAC= 1.6A4E+0
499      FT= 3.629E+08
500
501      NAME:  Q70      MODEL:  RN1LC
502
503      IB= 1.240E-06      IC= 1.876E-04      VBE= 6.6A3E-01      VBC= 0.000E+0
504      VCE= 6.6A3E-01      BETADC= 1.513E+02      GM= 7.260E-03      RPI= 2.320E+0
505      RO= 3.861E+05      CPI= 2.354E-12      CMU= 8.299E-13      BETAAC= 1.6A4E+0
506      FT= 3.629E+08
507
508      NAME:  Q71      MODEL:  RN1LC
509
510      IB= 4.795E-07      IC= 6.306E-05      VBE= 6.399E-01      VBC= 0.000E+0
511      VCE= 6.399E-01      BETADC= 1.315E+02      GM= 2.447E-03      RPI= 6.377E+0
512      RO= 1.151E+06      CPI= 1.620E-12      CMU= 8.094E-13      BETAAC= 1.561E+0
513      FT= 1.603E+08
514
515      NAME:  Q72      MODEL:  RP1LC
516
517      IB=-6.676E-07      IC=-7.622E-05      VBE=-6.540E-01      VBC= 0.000E+0
518      VCE=-6.540E-01      BETADC= 1.142E+02      GM= 2.957E-03      RPI= 4.303E+0
519      RO= 7.609E+05      CPI= 2.478E-12      CMU= 8.932E-13      BETAAC= 1.272E+0
520      FT= 1.396E+08
521
522      NAME:  Q73      MODEL:  RNO
523
524      IB=-7.364E-11      IC= 7.392E-11      VBE= 0.000E+00      VBC=-1.213E+0
525      VCE= 1.213E+01      BETADC=-1.004E+00      GM=-1.496E-14      RPI= 1.713E+1
526      RO= 3.882E+13      CPI= 4.500E-13      CMU= 2.707E-13      BETAAC=-2.562E-0
527      FT=-3.303E-03
528
529      NAME:  Q74      MODEL:  RN1
530
531      IB=-1.814E-10      IC= 1.821E-10      VBE=-6.367E-04      VBC=-1.495E+0
532      VCE= 1.494E+01      BETADC=-1.004E+00      GM=-3.684E-14      RPI= 8.564E+1
533      RO= 1.837E+13      CPI= 8.198E-13      CMU= 3.844E-13      BETAAC=-3.155E-0
534      FT=-4.869E-03
535
536      NAME:  Q75      MODEL:  RP1
537
538      IB= 1.269E-10      IC=-1.275E-10      VBE=-6.367E-04      VBC= 1.494E+0
539      VCE=-1.494E+01      BETADC=-1.004E+00      GM=-2.629E-14      RPI= 1.208E+1
540      RO= 2.450E+13      CPI= 9.502E-13      CMU= 2.473E-13      BETAAC=-3.176E-0
541      FT=-3.494E-03
542
543      NAME:  Q76      MODEL:  RP0
544
545      IB= 5.065E-12      IC=-5.081E-12      VBE= 0.000E+00      VBC= 1.192E+0
546      VCE=-1.192E+00      BETADC=-1.003E+00      GM=-1.0A3E-15      RPI= 2.447E+1
547      RO= 7.060E+13      CPI= 5.200E-13      CMU= 3.678E-13      BETAAC=-2.649E-0
548      FT=-1.941E-04
549
550      NAME:  Q77      MODEL:  RP1

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551
552      IR= 1.013E-11      IC=-1.016E-11      VBE= 0.000E+00      VBC= 1.192E+0
553      VCE=-1.192E+00      BETADC=-1.003E+00      GM=-2.166E-15      RPI= 1.223E+1
554      RO= 3.530E+13      CPI= 9.500E-13      CMU= 5.272E-13      BETAAC=-2.649E-0
555      FT=-2.333E-04
556
557      NAME:  Q78      MODEL:  RP0
558
559      IR= 5.065E-12      IC=-5.081E-12      VBE= 0.000E+00      VBC= 1.192E+0
560      VCE=-1.192E+00      BETADC=-1.003E+00      GM=-1.083E-15      RPI= 2.447E+1
561      RO= 7.060E+13      CPI= 5.200E-13      CMU= 3.678E-13      BETAAC=-2.649E-0
562      FT=-1.941E-04
563
564      NAME:  Q79      MODEL:  RN1
565
566      IR=-1.317E-11      IC= 1.321E-11      VBE= 0.000E+00      VBC=-1.085E+0
567      VCE= 1.085E+00      BETADC=-1.003E+00      GM=-2.674E-15      RPI= 8.564E+1
568      RO= 2.497E+13      CPI= 8.200E-13      CMU= 6.223E-13      BETAAC=-2.290E-0
569      FT=-2.951E-04
570
571      NAME:  Q80      MODEL:  RN1
572
573      IR=-1.317E-11      IC= 1.321E-11      VBE= 0.000E+00      VBC=-1.085E+0
574      VCE= 1.085E+00      BETADC=-1.003E+00      GM=-2.674E-15      RPI= 8.564E+1
575      RO= 2.497E+13      CPI= 8.200E-13      CMU= 6.223E-13      BETAAC=-2.290E-0
576      FT=-2.951E-04
577
578      NAME:  Q81      MODEL:  RN1
579
580      IR=-1.317E-11      IC= 1.321E-11      VBE= 0.000E+00      VBC=-1.085E+0
581      VCE= 1.085E+00      BETADC=-1.003E+00      GM=-2.674E-15      RPI= 8.564E+1
582      RO= 2.497E+13      CPI= 8.200E-13      CMU= 6.223E-13      BETAAC=-2.290E-0
583      FT=-2.951E-04
584
585      NAME:  Q82      MODEL:  RN1
586
587      IR=-1.317E-11      IC= 1.321E-11      VBE= 0.000E+00      VBC=-1.085E+0
588      VCE= 1.085E+00      BETADC=-1.003E+00      GM=-2.674E-15      RPI= 8.564E+1
589      RO= 2.497E+13      CPI= 8.200E-13      CMU= 6.223E-13      BETAAC=-2.290E-0
590      FT=-2.951E-04
591
592      NAME:  Q83      MODEL:  RP0
593
594      IR= 6.721E-11      IC=-6.748E-11      VBE= 0.000E+00      VBC= 1.582E+0
595      VCE=-1.582E+01      BETADC=-1.004E+00      GM=-1.437E-14      RPI= 2.447E+1
596      RO= 4.806E+13      CPI= 5.200E-13      CMU= 1.694E-13      BETAAC=-3.516E-0
597      FT=-3.317E-03
598
599      NAME:  Q84      MODEL:  RN8C
600
601      IR=-1.330E-10      IC= 1.335E-10      VBE= 0.000E+00      VBC=-1.370E+0
602      VCE= 1.370E+00      BETADC=-1.003E+00      GM=-2.702E-14      RPI= 1.070E+1
603      RO= 3.098E+12      CPI= 6.200E-12      CMU= 2.853E-12      BETAAC=-2.892E-0
604      FT=-4.749E-04
605

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21:51:17

HARRIS SLASH/8

PAGE

606 NAME: Q85 MODEL: RNO
607
608 IR=-1.285E-11 IC= 1.289E-11 VRF= 0.000E+00 VBC=-2.118F+
609 VCF= 2.118E+00 BETADC=-1.003E+00 GM=-2.610E-15 RPI= 1.713E+
610 RO= 4.864E+13 CPI= 4.500E-13 CMU= 3.774E-13 BETAAC=-4.471E-
611 FT=-5.021E-04

3

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1 DINS PHOTOPREAMPLIFIER OPERATING POINTS (TEMPERATURE 125 DEGRFES C)
2
3
4 ----- VOLTAGE SUPPLY CURRENTS -----
5
6 NAME CURRNT NAME CURRNT
7 VPOS -3.430E-03 VNFG 3.894E-03 TOTAL POWER = 110 MW (ONE CHANNEL)
8
9
10 ----- ZENER DIODE -----
11
12 NAME: DZ1 MODEL: DZR
13
14 ID=-2.774E-04 VD=-6.460E+00 PEG= 1.259E+02 CAP= 1.297E-
15
16 ----- RJT'S -----
17
18 NAME: Q1 MODEL: RP0
19
20 IB= 3.197E-08 IC=-6.922E-05 VBF=-4.873E-01 VBC= 1.294E+0
21 VCE=-1.343E+01 BETAOC=-2.165E+03 GM= 1.996E-03 RPI= 1.008E+0
22 RO= 1.035E+06 CPI= 1.375E-12 CMU= 1.386E-13 BETAAC= 2.012E+0
23 FT= 2.099E+08
24
25 NAME: Q2 MODEL: RP0
26
27 IB= 3.242E-08 IC=-6.975E-05 VBF=-4.875E-01 VBC= 1.303E+0
28 VCE=-1.351E+01 BETAOC=-2.151E+03 GM= 2.012E-03 RPI= 1.002E+0
29 RO= 1.717E+06 CPI= 1.379E-12 CMU= 1.383E-13 BETAAC= 2.016E+0
30 FT= 2.110E+08
31
32 NAME: Q3 MODEL: RN0
33
34 IB=-3.591E-07 IC= 5.092E-05 VBE= 4.651E-01 VBC=-1.349E+0
35 VCE= 1.395E+01 BETAOC=-1.418E+02 GM= 1.460E-03 RPI= 1.569E+0
36 RO= 1.717E+06 CPI= 8.572E-13 CMU= 2.371E-13 BETAAC= 2.291E+0
37 FT= 2.124E+08
38
39 NAME: Q4 MODEL: RN1
40
41 IB= 4.037E-07 IC= 7.014E-05 VBE= 4.586E-01 VBC=-5.488E-0
42 VCE= 1.007E+00 BETAOC= 1.737E+02 GM= 2.036E-03 RPI= 9.380E+0
43 RO= 1.048E+06 CPI= 1.521E-12 CMU= 6.511E-13 BETAAC= 1.909E+0
44 FT= 1.492E+08
45
46 NAME: Q5 MODEL: RN1
47
48 IB= 4.118E-07 IC= 7.010E-05 VBE= 4.586E-01 VBC=-4.651E-0
49 VCE= 9.237E-01 BETAOC= 1.703E+02 GM= 2.035E-03 RPI= 9.374E+0
50 RO= 1.048E+06 CPI= 1.521E-12 CMU= 6.681E-13 BETAAC= 1.907E+0
51 FT= 1.479E+08
52
53 NAME: Q6 MODEL: RN1
54
55 IB= 1.902E-07 IC= 2.487E-05 VBE= 4.230E-01 VBC=-1.075E-0

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HARRIS CORP MELBOURNE FL

F/6 9/1

DINS FINAL REPORT.(U)

OCT 79 C P HERNANDEZ, J W BOARMAN

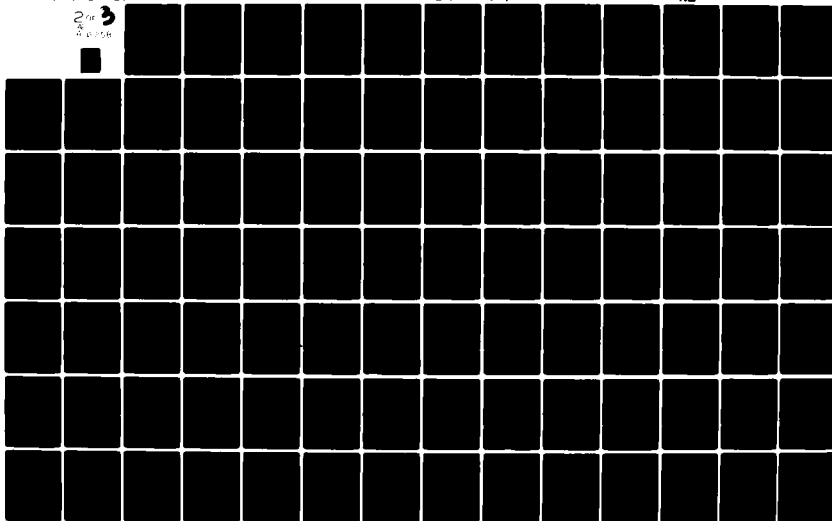
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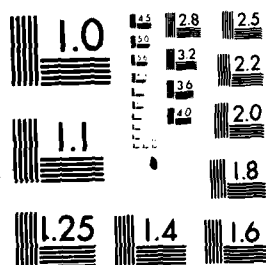
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NL

2 of 3
3
10/10



2 OF 3
AD
A/12258



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

56	VCE= 5.305E-01	BETAOC= 1.308E+02	GM= 7.228E-04	RPI= 2.297E+
57	RO= 2.927E+06	CPI= 1.289E-12	CMU= 7.611E-13	BETAAC= 1.660E+
58	FT= 5.610E+07			
59				
60	NAME: Q7	MODEL: RN1		
61				
62	IB= 1.902E-07	IC= 2.487E-05	VBE= 4.230E-01	VBC= -1.075E-
63	VCE= 5.305E-01	BETAOC= 1.308E+02	GM= 7.228E-04	RPI= 2.297E+
64	RO= 2.927E+06	CPI= 1.289E-12	CMU= 7.611E-13	BETAAC= 1.660E+
65	FT= 5.610E+07			
66				
67	NAME: Q8	MODEL: RP0		
68				
69	IB= -2.723E-07	IC= -1.394E-04	VBE= -5.112E-01	VBC= 1.404E+
70	VCE= -1.455E+01	BETAOC= 5.120E+02	GM= 4.023E-03	RPI= 5.229E+
71	RO= 5.185E+05	CPI= 1.983E-12	CMU= 1.355E-13	BETAAC= 2.104E+
72	FT= 3.022E+08			
73				
74	NAME: Q9	MODEL: RP1		
75				
76	IB= -1.812E-06	IC= -2.826E-04	VBE= -5.196E-01	VBC= 4.576E-
77	VCE= -9.772E-01	BETAOC= 1.559E+02	GM= 8.172E-03	RPI= 2.097E+
78	RO= 2.021E+05	CPI= 4.453E-12	CMU= 1.393E-12	BETAAC= 1.714E+
79	FT= 2.225E+08			
80				
81	NAME: Q10	MODEL: RP1		
82				
83	IB= 5.154E-07	IC= -5.986E-05	VBE= -4.576E-01	VBC= 1.361E+
84	VCE= -1.407E+01	BETAOC= -1.162E+02	GM= 1.713E-03	RPI= 1.116E+
85	RO= 1.218E+06	CPI= 1.895E-12	CMU= 1.954E-13	BETAAC= 1.912E+
86	FT= 1.304E+08			
87				
88	NAME: Q11	MODEL: RN0		
89				
90	IB= 1.894E-07	IC= 2.821E-04	VBE= 5.222E-01	VBC= -2.056E+
91	VCE= 2.109E+01	BETAOC= 1.489E+03	GM= 8.107E-03	RPI= 3.375E+
92	RO= 3.306E+05	CPI= 1.651E-12	CMU= 2.183E-13	BETAAC= 2.736E+
93	FT= 6.903E+08			
94				
95	NAME: Q12	MODEL: RN0		
96				
97	IB= -3.698E-07	IC= 4.762E-05	VBE= 4.628E-01	VBC= -1.340E+
98	VCE= 1.387E+01	BETAOC= -1.288E+02	GM= 1.364E-03	RPI= 1.666E+
99	RO= 1.835E+06	CPI= 8.440E-13	CMU= 2.374E-13	BETAAC= 2.274E+
100	FT= 2.008E+08			
101				
102	NAME: Q13	MODEL: RN1		
103				
104	IB= 3.133E-07	IC= 4.733E-05	VBE= 4.452E-01	VBC= -1.934E-
105	VCE= 6.386E-01	BETAOC= 1.511E+02	GM= 1.375E-03	RPI= 1.323E+
106	RO= 1.545E+06	CPI= 1.410E-12	CMU= 7.377E-13	BETAAC= 1.818E+
107	FT= 1.019E+08			
108				
109	NAME: Q14	MODEL: RN1		
110				

111	IB= 1.487E-06	IC= 2.832E-04	VBF= 5.073E-01	VBC=-4.459E-
112	VCE= 9.532E-01	BETAOC= 1.905E+02	GM= 8.189E-03	RPI= 2.579E+
113	RO= 2.581E+05	CPI= 2.480E-12	CMU= 7.698E-13	BETAAC= 2.112E+
114	FT= 4.010E+08			
115				
116	NAME: Q15	MODEL: RP0		
117				
118	IB=-8.020E-07	IC=-2.439E-04	VBF=-5.312E-01	VBC= 1.357E+
119	VCE=-1.410E+01	BETAOC= 3.042E+02	GM= 7.026E-03	RPI= 3.008E+
120	RO= 2.926E+05	CPI= 2.920E-12	CMU= 1.381E-13	BETAAC= 2.114E+
121	FT= 3.657E+08			
122				
123	NAME: Q16	MODEL: RN1LC		
124				
125	IB= 1.554E-06	IC= 2.445E-04	VBF= 5.024E-01	VBC= 0.000E+
126	VCE= 5.024E-01	BETAOC= 1.574E+02	GM= 7.082E-03	RPI= 2.950E+
127	RO= 2.289E+05	CPI= 2.315E-12	CMU= 1.132E-12	BETAAC= 2.089E+
128	FT= 3.270E+08			
129				
130	NAME: Q17	MODEL: PP1LC		
131				
132	IB=-1.988E-06	IC=-2.441E-04	VBF=-5.147E-01	VBC= 0.000E+
133	VCE=-5.147E-01	BETAOC= 1.227E+02	GM= 7.074E-03	RPI= 2.407E+
134	RO= 1.441E+05	CPI= 4.047E-12	CMU= 3.323E-12	BETAAC= 1.702E+
135	FT= 1.528E+08			
136				
137	NAME: Q18	MODEL: RN1		
138				
139	IB=-9.236E-07	IC= 5.929E-05	VBF= 4.459E-01	VBC=-1.361E+
140	VCE= 1.406E+01	BETAOC=-6.420E+01	GM= 1.685E-03	RPI= 1.282E+
141	RO= 1.488E+06	CPI= 1.419E-12	CMU= 3.506E-13	BETAAC= 2.160E+
142	FT= 1.516E+08			
143				
144	NAME: Q19	MODEL: RN1		
145				
146	IB=-7.990E-08	IC= 2.452E-04	VBF= 4.959E-01	VBC=-1.335E+
147	VCE= 1.385E+01	BETAOC=-3.069E+03	GM= 7.068E-03	RPI= 3.459E+
148	RO= 3.526E+05	CPI= 2.146E-12	CMU= 3.534E-13	BETAAC= 2.445E+
149	FT= 4.501E+08			
150				
151	NAME: Q20	MODEL: RN1LC		
152				
153	IB= 1.546E-06	IC= 2.436E-04	VBF= 5.023E-01	VBC= 0.000E+
154	VCE= 5.023E-01	BETAOC= 1.576E+02	GM= 7.056E-03	RPI= 2.960E+
155	RO= 2.307E+05	CPI= 2.311E-12	CMU= 1.128E-12	BETAAC= 2.089E+
156	FT= 3.265E+08			
157				
158	NAME: Q21	MODEL: RN4		
159				
160	IB=-2.505E-06	IC= 5.758E-04	VBF= 4.765E-01	VBC=-1.446E+
161	VCE= 1.494E+01	BETAOC=-2.299E+02	GM= 1.655E-02	RPI= 1.441E+
162	RO= 1.530E+05	CPI= 6.886E-12	CMU= 9.974E-13	BETAAC= 2.385E+
163	FT= 3.341E+08			
164				
165	NAME: Q22	MODEL: RP4		

166
167 IR= 5.746E-07 IC= -5.748E-04 VBF= -4.879E-01 VBC= 1.445E+0
168 VCE= -1.494E+01 BETADC= -1.000E+03 GM= 1.657E-02 RPI= 1.240E+0
169 RO= 1.271E+05 CPI= 1.039E-11 CMU= 5.604E-13 BETAAC= 2.054E+0
170 FT= 2.408E+08
171
172 NAME: Q23 MODEL: RN1LC
173
174 IR= 4.580E-07 IC= 7.008E-05 VBE= 4.588E-01 VBC= 0.000E+0
175 VCE= 4.588E-01 BETADC= 1.530E+02 GM= 2.035E-03 RPI= 9.323E+0
176 RO= 1.027E+06 CPI= 1.523E-12 CMU= 8.423E-13 BETAAC= 1.898E+0
177 FT= 1.370E+08
178
179 NAME: Q24 MODEL: RN1LC
180
181 IR= 4.579E-07 IC= 7.006E-05 VBE= 4.588E-01 VBC= 0.000E+0
182 VCE= 4.588E-01 BETADC= 1.530E+02 GM= 2.035E-03 RPI= 9.325E+0
183 RO= 1.027E+06 CPI= 1.523E-12 CMU= 8.423E-13 BETAAC= 1.896E+0
184 FT= 1.369E+08
185
186 NAME: Q25 MODEL: RN1LC
187
188 IR= 3.800E-07 IC= 5.600E-05 VBE= 4.511E-01 VBC= 0.000E+0
189 VCE= 4.511E-01 BETADC= 1.474E+02 GM= 1.627E-03 RPI= 1.138E+0
190 RO= 1.288E+06 CPI= 1.454E-12 CMU= 8.327E-13 BETAAC= 1.851E+0
191 FT= 1.132E+08
192
193 NAME: Q26 MODEL: RP1LC
194
195 IR= -4.210E-07 IC= -5.592E-05 VBF= -4.633E-01 VBC= 0.000E+0
196 VCE= -4.633E-01 BETADC= 1.328E+02 GM= 1.624E-03 RPI= 9.683E+0
197 RO= 1.035E+06 CPI= 1.986E-12 CMU= 1.009E-12 BETAAC= 1.573E+0
198 FT= 8.632E+07
199
200 NAME: Q27 MODEL: RN1LC
201
202 IR= 1.809E-06 IC= 2.706E-04 VBE= 5.060E-01 VBC= 0.000E+0
203 VCE= 5.060E-01 BETADC= 1.496E+02 GM= 7.838E-03 RPI= 2.679E+0
204 RO= 1.789E+05 CPI= 2.431E-12 CMU= 1.261E-12 BETAAC= 2.099E+0
205 FT= 3.378E+08
206
207 NAME: Q28 MODEL: RN1LC
208
209 IR= 1.809E-06 IC= 2.706E-04 VBE= 5.060E-01 VBC= 0.000E+0
210 VCE= 5.060E-01 BETADC= 1.496E+02 GM= 7.838E-03 RPI= 2.679E+0
211 RO= 1.789E+05 CPI= 2.431E-12 CMU= 1.261E-12 BETAAC= 2.099E+0
212 FT= 3.378E+08
213
214 NAME: Q29 MODEL: RN1LC
215
216 IR= 1.809E-06 IC= 2.706E-04 VBE= 5.060E-01 VBC= 0.000E+0
217 VCE= 5.060E-01 BETADC= 1.496E+02 GM= 7.838E-03 RPI= 2.679E+0
218 RO= 1.789E+05 CPI= 2.431E-12 CMU= 1.261E-12 BETAAC= 2.099E+0
219 FT= 3.378E+08
220

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221 NAME: Q30      MODEL: RNO
222
223 IR=-5.991E-07   IC= 6.239E-07   VBE= 0.000E+00   VBC=-1.289E+
224 VCE= 1.249E+01  BETADC=-1.041E+00   GM=-1.322E-09   RPI= 6.762E+
225 RO= 4.540E+08   CPI= 4.501E-13   CMU= 2.389E-13  BETAAC=-8.941E-
226 FT=-3.054E+02
227
228 NAME: Q31      MODEL: RNO
229
230 IR=-3.687E-07   IC= 6.511E-05   VBE= 4.731E-01   VBC=-1.494E+
231 VCE= 1.541E+01  BETADC=-1.766E+02   GM= 1.869E-03   RPI= 1.272E+
232 RO= 1.363E+06   CPI= 9.090E-13   CMU= 2.322E-13  BETAAC= 2.378E+
233 FT= 2.607E+08
234
235 NAME: Q32      MODEL: RNO
236
237 IR=-3.687E-07   IC= 6.511E-05   VBE= 4.731E-01   VBC=-1.494E+
238 VCE= 1.541E+01  BETADC=-1.766E+02   GM= 1.869E-03   RPI= 1.272E+
239 RO= 1.363E+06   CPI= 9.090E-13   CMU= 2.322E-13  BETAAC= 2.378E+
240 FT= 2.607E+08
241
242 NAME: Q33      MODEL: RNO
243
244 IR=-3.039E-07   IC= 6.471E-05   VBE= 4.734E-01   VBC=-1.360E+
245 VCE= 1.407E+01  BETADC=-2.130E+02   GM= 1.860E-03   RPI= 1.261E+
246 RO= 1.349E+06   CPI= 9.115E-13   CMU= 2.368E-13  BETAAC= 2.344E+
247 FT= 2.577E+08
248
249 NAME: Q34      MODEL: RNO
250
251 IR=-3.039E-07   IC= 6.471E-05   VBE= 4.734E-01   VBC=-1.360E+
252 VCE= 1.407E+01  BETADC=-2.130E+02   GM= 1.860E-03   RPI= 1.261E+
253 RO= 1.349E+06   CPI= 9.115E-13   CMU= 2.368E-13  BETAAC= 2.344E+
254 FT= 2.577E+08
255
256 NAME: Q35      MODEL: RPO
257
258 IR= 2.870E-08   IC=-2.973E-08   VBE= 0.000E+00   VBC= 8.817E-
259 VCE=-8.817E-01  BETADC=-1.036E+00   GM=-6.709E-11   RPI= 9.686E+
260 RO= 8.466E+08   CPI= 5.200E-13   CMU= 3.181E-13  BETAAC=-6.498E-
261 FT=-1.274E+01
262
263 NAME: Q36      MODEL: RPI
264
265 IR= 5.740E-08   IC=-5.946E-08   VBE= 0.000E+00   VBC= 8.817E-
266 VCE=-8.817E-01  BETADC=-1.036E+00   GM=-1.337E-10   RPI= 4.843E+
267 RO= 4.233E+08   CPI= 9.500E-13   CMU= 4.563E-13  BETAAC=-6.475E-
268 FT=-1.513E+01
269
270 NAME: Q37      MODEL: RPO
271
272 IR= 2.870E-08   IC=-2.973E-08   VBE= 0.000E+00   VBC= 8.817E-
273 VCE=-8.817E-01  BETADC=-1.036E+00   GM=-6.709E-11   RPI= 9.686E+
274 RO= 8.466E+08   CPI= 5.200E-13   CMU= 3.181E-13  BETAAC=-6.498E-
275 FT=-1.274E+01

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276
277 NAME: Q38 MODEL: RN1
278
279 IB=-8.086E-08 IC= 8.375E-08 VBE= 0.000E+00 VBC=-8.698E-0
280 VCE= 8.698E-01 BETADC=-1.036E+00 GM=-1.776E-10 RPI= 3.393E+0
281 RO= 2.981E+08 CPI= 8.200E-13 CMU= 5.916E-13 BETAAC=-6.025E-0
282 FT=-2.002E+01
283
284 NAME: Q39 MODEL: RN1
285
286 IB=-8.086E-08 IC= 8.375E-08 VBE= 0.000E+00 VBC=-8.698E-0
287 VCE= 8.698E-01 BETADC=-1.036E+00 GM=-1.776E-10 RPI= 3.393E+0
288 RO= 2.981E+08 CPI= 8.200E-13 CMU= 5.916E-13 BETAAC=-6.025E-0
289 FT=-2.002E+01
290
291 NAME: Q40 MODEL: RN1
292
293 IB=-8.086E-08 IC= 8.375E-08 VBE= 0.000E+00 VBC=-8.698E-0
294 VCE= 8.698E-01 BETADC=-1.036E+00 GM=-1.776E-10 RPI= 3.393E+0
295 RO= 2.981E+08 CPI= 8.200E-13 CMU= 5.916E-13 BETAAC=-6.025E-0
296 FT=-2.002E+01
297
298 NAME: Q41 MODEL: RN1
299
300 IB=-8.086E-08 IC= 8.375E-08 VBE= 0.000E+00 VBC=-8.698E-0
301 VCE= 8.698E-01 BETADC=-1.036E+00 GM=-1.776E-10 RPI= 3.393E+0
302 RO= 2.981E+08 CPI= 8.200E-13 CMU= 5.916E-13 BETAAC=-6.025E-0
303 FT=-2.002E+01
304
305 NAME: Q42 MODEL: RP0
306
307 IB= 4.869E-07 IC=-5.084E-07 VBE= 0.000E+00 VBC= 1.496E+0
308 VCE=-1.496E+01 BETADC=-1.044E+00 GM=-1.137E-09 RPI= 9.663E+0
309 RO= 5.816E+08 CPI= 5.200E-13 CMU= 1.316E-13 BETAAC=-1.098E+0
310 FT=-2.776E+02
311
312 NAME: Q43 MODEL: RN4
313
314 IB=-3.782E-07 IC= 3.917E-07 VBE= 0.000E+00 VBC=-1.017E+0
315 VCE= 1.017E+00 BETADC=-1.036E+00 GM=-8.166E-10 RPI= 8.478E+0
316 RO= 7.424E+07 CPI= 3.200E-12 CMU= 1.658E-12 BETAAC=-6.924E-0
317 FT=-2.675E+01
318
319 NAME: Q44 MODEL: RN0
320
321 IB=-7.094E-08 IC= 7.349E-08 VBE= 0.000E+00 VBC=-1.526E+0
322 VCE= 1.526E+00 BETADC=-1.036E+00 GM=-1.568E-10 RPI= 6.787E+0
323 RO= 5.862E+08 CPI= 4.500E-13 CMU= 3.629E-13 BETAAC=-1.064E-0
324 FT=-3.070E+01
325
326 NAME: Q45 MODEL: RN0
327
328 IB=-4.043E-08 IC= 4.187E-08 VBE= 0.000E+00 VBC=-8.698E-0
329 VCE= 8.698E-01 BETADC=-1.036E+00 GM=-8.937E-11 RPI= 6.788E+0
330 RO= 5.962E+08 CPI= 4.500E-13 CMU= 3.993E-13 BETAAC=-6.067E-0

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331      FT=-1.675E+01
332
333  NAME:  Q46      MODEL:  RN0
334
335      IB=-4.043E-08      IC= 4.187E-08      VBE= 0.000E+00      VBC=-8.69AF-
336      VCE= 8.698E-01      BETADC=-1.036E+00      GM=-8.937E-11      RPI= 6.788E+
337      RO= 5.962E+08      CPI= 4.500E-13      CMU= 3.993E-13      BETAAC=-6.067E-
338      FT=-1.675E+01
339
340  NAME:  Q47      MODEL:  RP0
341
342      IB=-5.235E-07      IC=-1.846E-04      VBE=-5.214E-01      VBC= 1.334E+
343      VCE=-1.386E+01      BETADC= 3.527E+02      GM= 5.325E-03      RPI= 3.941E+
344      RO= 3.866E+05      CPI= 2.397E-12      CMU= 1.383E-13      BETAAC= 2.099E+
345      FT= 3.342E+08
346
347  NAME:  Q48      MODEL:  RP0
348
349      IB=-5.269E-07      IC=-1.852E-04      VBE=-5.216E-01      VBC= 1.332E+
350      VCE=-1.384E+01      BETADC= 3.515E+02      GM= 5.342E-03      RPI= 3.929E+
351      RO= 3.853E+05      CPI= 2.403E-12      CMU= 1.384E-13      BETAAC= 2.099E+
352      FT= 3.345E+08
353
354  NAME:  Q49      MODEL:  RN0
355
356      IB=-3.463E-07      IC= 5.199E-05      VBE= 4.659E-01      VBC=-1.332E+
357      VCE= 1.379E+01      BETADC=-1.501E+02      GM= 1.491E-03      RPI= 1.537E+
358      RO= 1.678E+06      CPI= 8.618E-13      CMU= 2.377E-13      BETAAC= 2.291E+
359      FT= 2.158E+08
360
361  NAME:  Q50      MODEL:  RN1
362
363      IB= 1.005E-06      IC= 1.855E-04      VBE= 4.924E-01      VBC=-4.520E-
364      VCE= 9.444E-01      BETADC= 1.846E+02      GM= 5.375E-03      RPI= 3.844E+
365      RO= 3.949E+05      CPI= 2.047E-12      CMU= 7.138E-13      BETAAC= 2.066E+
366      FT= 3.098E+08
367
368  NAME:  Q51      MODEL:  RN1
369
370      IB= 1.004E-06      IC= 1.855E-04      VBE= 4.924E-01      VBC=-4.659E-
371      VCE= 9.583E-01      BETADC= 1.849E+02      GM= 5.375E-03      RPI= 3.845E+
372      RO= 3.950E+05      CPI= 2.047E-12      CMU= 7.094E-13      BETAAC= 2.066E+
373      FT= 3.103E+08
374
375  NAME:  Q52      MODEL:  RN1
376
377      IB= 1.799E-07      IC= 2.482E-05      VBE= 4.229E-01      VBC=-2.114E-
378      VCE= 6.342E-01      BETADC= 1.380E+02      GM= 7.208E-04      RPI= 2.305E+
379      RO= 2.939E+06      CPI= 1.289E-12      CMU= 7.200E-13      BETAAC= 1.661E+
380      FT= 5.711E+07
381
382  NAME:  Q53      MODEL:  RN1
383
384      IB= 1.799E-07      IC= 2.482E-05      VBE= 4.229E-01      VBC=-2.114E-
385      VCE= 6.342E-01      BETADC= 1.380E+02      GM= 7.208E-04      RPI= 2.305E+

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386 RO= 2.939E+06 CPI= 1.289E-12 CMU= 7.200E-13 BETAAC= 1.661E+0
 387 FT= 5.711E+07
 388
 389 NAME: Q54 MODEL: RP0
 390
 391 IB=-1.447E-06 IC=-3.714E-04 VBE=-5.464E-01 VBC= 1.317E+0
 392 VCE=-1.372E+01 BETADC= 2.547E+02 GM= 1.046E-02 RPI= 1.971E+0
 393 RO= 1.899E+05 CPI= 4.084E-12 CMU= 1.404E-13 BETAAC= 2.101E+0
 394 FT= 4.015E+08
 395
 396 NAME: Q55 MODEL: RP1
 397
 398 IB=-2.255E-06 IC=-3.270E-04 VBE=-5.248E-01 VBC= 4.690E-0
 399 VCE=-9.939E-01 BETADC= 1.450E+02 GM= 9.451E-03 RPI= 1.818E+0
 400 RO= 1.499E+05 CPI= 4.938E-12 CMU= 2.275E-12 BETAAC= 1.718E+0
 401 FT= 2.085E+08
 402
 403 NAME: Q56 MODEL: RP1
 404
 405 IB= 3.809E-07 IC=-8.266E-05 VBE=-4.690E-01 VBC= 1.342E+0
 406 VCE=-1.389E+01 BETADC=-2.170E+02 GM= 2.375E-03 RPI= 8.241E+0
 407 RO= 8.761E+05 CPI= 2.106E-12 CMU= 1.965E-13 BETAAC= 1.958E+0
 408 FT= 1.642E+08
 409
 410 NAME: Q57 MODEL: RN0
 411
 412 IB= 3.686E-07 IC= 3.266E-04 VBE= 5.275E-01 VBC=-2.037E+0
 413 VCE= 2.090E+01 BETADC= 8.861E+02 GM= 9.377E-03 RPI= 2.922E+0
 414 RO= 2.845E+05 CPI= 1.807E-12 CMU= 2.190E-13 BETAAC= 2.740E+0
 415 FT= 7.365E+08
 416
 417 NAME: Q58 MODEL: RN0
 418
 419 IB=-3.648E-07 IC= 4.803E-05 VBE= 4.631E-01 VBC=-1.334E+0
 420 VCE= 1.380E+01 BETADC=-1.317E+02 GM= 1.376E-03 RPI= 1.652E+0
 421 RO= 1.818E+06 CPI= 8.458E-13 CMU= 2.376E-13 BETAAC= 2.274E+0
 422 FT= 2.022E+08
 423
 424 NAME: Q59 MODEL: RN1
 425
 426 IB= 3.134E-07 IC= 4.748E-05 VBE= 4.453E-01 VBC=-2.002E-0
 427 VCE= 6.455E-01 BETADC= 1.515E+02 GM= 1.379E-03 RPI= 1.319E+0
 428 RO= 1.540E+06 CPI= 1.411E-12 CMU= 7.352E-13 BETAAC= 1.819E+0
 429 FT= 1.023E+08
 430
 431 NAME: Q60 MODEL: RN1
 432
 433 IB= 1.704E-06 IC= 3.278E-04 VBE= 5.125E-01 VBC=-4.507E-0
 434 VCE= 9.631E-01 BETADC= 1.924E+02 GM= 9.471E-03 RPI= 2.243E+0
 435 RO= 2.227E+05 CPI= 2.677E-12 CMU= 8.015E-13 BETAAC= 2.124E+0
 436 FT= 4.333E+08
 437
 438 NAME: Q61 MODEL: RP0
 439
 440 IB=-1.076E-06 IC=-2.995E-04 VBE=-5.385E-01 VBC= 1.350E+0

441	VCF=-1.404E+01	BETAOC= 2.784E+02	GM= 8.614E-03	RPI= 2.454E+0
442	RO= 2.374E+05	CPI= 3.420E-12	CMU= 1.389E-13	BETAAC= 2.114E+0
443	FT= 3.853E+08			
444				
445	NAME: Q62	MODEL: RNILC		
446				
447	IB= 2.218E-06	IC= 3.026E-04	VBE= 5.101E-01	VBC= 0.000E+0
448	VCE= 5.101E-01	BETAOC= 1.364E+02	GM= 8.764E-03	RPI= 2.407E+0
449	RO= 1.231E+05	CPI= 2.574E-12	CMU= 1.540E-12	BETAAC= 2.110E+0
450	FT= 3.391E+08			
451				
452	NAME: Q63	MODEL: RPILC		
453				
454	IB=-3.300E-06	IC=-3.016E-04	VBE=-5.226E-01	VBC= 0.000E+0
455	VCE=-5.226E-01	BETAOC= 9.138E+01	GM= 8.755E-03	RPI= 1.953E+0
456	RO= 5.066E+04	CPI= 4.647E-12	CMU= 9.766E-12	BETAAC= 1.709E+0
457	FT= 9.641E+07			
458				
459	NAME: Q64	MODEL: RN1		
460				
461	IB=-8.774E-07	IC= 6.777E-05	VBE= 4.507E-01	VBC=-1.355E+0
462	VCE= 1.400E+01	BETAOC=-7.724E+01	GM= 1.932E-03	RPI= 1.136E+0
463	RO= 1.298E+06	CPI= 1.455E-12	CMU= 3.510E-13	BETAAC= 2.194E+0
464	FT= 1.702E+08			
465				
466	NAME: Q65	MODEL: RN1		
467				
468	IB= 1.839E-07	IC= 3.028E-04	VBE= 5.035E-01	VBC=-1.315E+0
469	VCE= 1.366E+01	BETAOC= 1.646E+03	GM= 8.728E-03	RPI= 2.826E+0
470	RO= 2.843E+05	CPI= 2.365E-12	CMU= 3.550E-13	BETAAC= 2.467E+0
471	FT= 5.107E+08			
472				
473	NAME: Q66	MODEL: RNILC		
474				
475	IB= 2.191E-06	IC= 3.008E-04	VBE= 5.099E-01	VBC= 0.000E+0
476	VCE= 5.099E-01	BETAOC= 1.373E+02	GM= 8.712E-03	RPI= 2.421E+0
477	RO= 1.260E+05	CPI= 2.566E-12	CMU= 1.519E-12	BETAAC= 2.109E+0
478	FT= 3.394E+08			
479				
480	NAME: Q67	MODEL: RNAC		
481				
482	IB=-6.122E-06	IC= 9.170E-04	VBE= 4.682E-01	VBC=-1.456E+0
483	VCE= 1.503E+01	BETAOC=-1.498E+02	GM= 2.630E-02	RPI= 8.902E+0
484	RO= 9.643E+04	CPI= 1.256E-11	CMU= 1.645E-12	BETAAC= 2.342E+0
485	FT= 2.947E+08			
486				
487	NAME: Q68	MODEL: RPAC		
488				
489	IB= 2.221E-06	IC=-9.224E-04	VBE=-4.802E-01	VBC= 1.430E+0
490	VCE=-1.478E+01	BETAOC=-4.152E+02	GM= 2.656E-02	RPI= 7.625E+0
491	RO= 7.425E+04	CPI= 1.865E-11	CMU= 8.999E-13	BETAAC= 2.025E+0
492	FT= 2.163E+08			
493				
494	NAME: Q69	MODEL: RNILC		
495				

496	IB= 1.116E-04	IC= 1.854E-04	VBF= 4.926E-01	VBC= 0.000E+
497	VCE= 4.926E-01	BETADC= 1.661E+02	GM= 5.374E-03	RPI= 3.827E+
498	RO= 3.580E+05	CPI= 2.051E-12	CMU= 9.754E-13	BETAAC= 2.057E+
499	FT= 2.826E+08			
500				
501	NAME: Q70	MODEL: RN1LC		
502				
503	IB= 1.117E-06	IC= 1.854E-04	VBF= 4.926E-01	VBC= 0.000E+
504	VCE= 4.926E-01	BETADC= 1.661E+02	GM= 5.375E-03	RPI= 3.827E+
505	RO= 3.580E+05	CPI= 2.051E-12	CMU= 9.754E-13	BETAAC= 2.057E+
506	FT= 2.826E+08			
507				
508	NAME: Q71	MODEL: RN1LC		
509				
510	IB= 4.230E-07	IC= 6.374E-05	VBE= 4.555E-01	VBC= 0.000E+
511	VCE= 4.555E-01	BETADC= 1.507E+02	GM= 1.851E-03	RPI= 1.015E+
512	RO= 1.130E+06	CPI= 1.492E-12	CMU= 8.379E-13	BETAAC= 1.878E+
513	FT= 1.265E+08			
514				
515	NAME: Q72	MODEL: RP1LC		
516				
517	IB=-5.574E-07	IC=-7.680E-05	VBE=-4.742E-01	VBC= 0.000E+
518	VCE=-4.742E-01	BETADC= 1.378E+02	GM= 2.230E-03	RPI= 7.220E+
519	RO= 7.496E+05	CPI= 2.219E-12	CMU= 1.100E-12	BETAAC= 1.610E+
520	FT= 1.069E+08			
521				
522	NAME: Q73	MODEL: RN0		
523				
524	IB=-5.899E-07	IC= 6.142E-07	VBE= 0.000E+00	VBC=-1.269E+
525	VCE= 1.269E+01	BETADC=-1.041E+00	GM=-1.302E-09	RPI= 6.763E+
526	RO= 4.558E+08	CPI= 4.501E-13	CMU= 2.397E-13	BETAAC=-8.804E-
527	FT=-3.004E+02			
528				
529	NAME: Q74	MODEL: RN1		
530				
531	IB=-1.400E-06	IC= 1.460E-06	VBE=-1.658E-05	VBC=-1.506E+
532	VCE= 1.506E+01	BETADC=-1.042E+00	GM=-3.067E-09	RPI= 3.369E+
533	RO= 2.176E+08	CPI= 8.202E-13	CMU= 3.429E-13	BETAAC=-1.033E+
534	FT=-4.196E+02			
535				
536	NAME: Q75	MODEL: RP1		
537				
538	IB= 9.641E-07	IC=-1.006E-06	VBE=-1.658E-05	VBC= 1.481E+
539	VCE=-1.481E+01	BETADC=-1.044E+00	GM=-2.240E-09	RPI= 4.822E+
540	RO= 2.918E+08	CPI= 9.502E-13	CMU= 1.895E-13	BETAAC=-1.080E+
541	FT=-3.127E+02			
542				
543	NAME: Q76	MODEL: RP0		
544				
545	IB= 3.410E-08	IC=-3.537E-08	VBE= 0.000E+00	VBC= 1.049E+
546	VCE=-1.049E+00	BETADC=-1.036E+00	GM=-7.980E-11	RPI= 9.686E+
547	RO= 8.421E+08	CPI= 5.200E-13	CMU= 3.028E-13	BETAAC=-7.729E-
548	FT=-1.544E+01			
549				
550	NAME: Q77	MODEL: RP1		

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551
552      IB= 6.424E-08      IC=-7.073E-08      VBE= 0.000E+00      VBC= 1.049E+0
553      VCE=-1.049E+00      BETA0C=-1.036E+00      GM=-1.590E-10      RPI= 4.842E+0
554      RO= 4.210E+08      CPI= 9.500E-13      CMU= 4.343E-13      BETAAC=-7.701E-0
555      FT=-1.828E+01
556
557      NAME:  Q78      MODEL:  RP0
558
559      IB= 3.414E-08      IC=-3.537E-08      VBE= 0.000E+00      VBC= 1.049E+0
560      VCE=-1.049E+00      BETA0C=-1.036E+00      GM=-7.940E-11      RPI= 9.646E+0
561      RO= 8.421E+08      CPI= 5.200E-13      CMU= 3.028E-13      BETAAC=-7.729E-0
562      FT=-1.544E+01
563
564      NAME:  Q79      MODEL:  RN1
565
566      IB=-8.665E-08      IC= 8.975E-08      VBE= 0.000E+00      VBC=-9.321E-0
567      VCE= 9.321E-01      BETA0C=-1.036E+00      GM=-1.903E-10      RPI= 3.393E+0
568      RO= 2.976E+08      CPI= 8.200E-13      CMU= 5.850E-13      BETAAC=-6.457E-0
569      FT=-2.155E+01
570
571      NAME:  Q80      MODEL:  RN1
572
573      IB=-8.665E-08      IC= 8.975E-08      VBE= 0.000E+00      VBC=-9.321E-0
574      VCE= 9.321E-01      BETA0C=-1.036E+00      GM=-1.903E-10      RPI= 3.393E+0
575      RO= 2.976E+08      CPI= 8.200E-13      CMU= 5.850E-13      BETAAC=-6.457E-0
576      FT=-2.155E+01
577
578      NAME:  Q81      MODEL:  RN1
579
580      IB=-8.665E-08      IC= 8.975E-08      VBE= 0.000E+00      VBC=-9.321E-0
581      VCE= 9.321E-01      BETA0C=-1.036E+00      GM=-1.903E-10      RPI= 3.393E+0
582      RO= 2.976E+08      CPI= 8.200E-13      CMU= 5.850E-13      BETAAC=-6.457E-0
583      FT=-2.155E+01
584
585      NAME:  Q82      MODEL:  RN1
586
587      IB=-8.665E-08      IC= 8.975E-08      VBE= 0.000E+00      VBC=-9.321E-0
588      VCE= 9.321E-01      BETA0C=-1.036E+00      GM=-1.903E-10      RPI= 3.393E+0
589      RO= 2.976E+08      CPI= 8.200E-13      CMU= 5.850E-13      BETAAC=-6.457E-0
590      FT=-2.155E+01
591
592      NAME:  Q83      MODEL:  RP0
593
594      IB= 5.095E-07      IC=-5.321E-07      VBE= 0.000E+00      VBC= 1.565E+0
595      VCE=-1.565E+01      BETA0C=-1.044E+00      GM=-1.189E-09      RPI= 9.661E+0
596      RO= 5.728E+08      CPI= 5.201E-13      CMU= 1.296E-13      BETAAC=-1.149E+0
597      FT=-2.914E+02
598
599      NAME:  Q84      MODEL:  RNAC
600
601      IB=-7.440E-07      IC= 7.955E-07      VBE= 0.000E+00      VBC=-1.033E+0
602      VCE= 1.033E+00      BETA0C=-1.036E+00      GM=-1.647E-09      RPI= 4.238E+0
603      RO= 3.711E+07      CPI= 6.200E-12      CMU= 2.734E-12      BETAAC=-6.941E-0
604      FT=-2.934E+01
605

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606	NAME: QAS	MODEL: RNO		
607				
608	IR=-7.416E-08	IC= 7.643E-08	VBE= 0.000E+00	VBC=-1.595E+00
609	VCE= 1.595E+00	RFTADC=-1.036E+00	GM=-1.639E-10	RPI= 6.786E+00
610	R0= 5.852E+08	CPI= 4.500E-13	CMU= 3.600E-13	HETAAC=-1.112E-01
611	FT=-3.221E+01			

1 OINS PHOTOPREAMPLIFIER OPERATING POINTS (TEMPERATURE -55 DEGREES C)

2
3

4 ----- VOLTAGE SUPPLY CURRENTS -----

6 NAME CURRENT NAME CURRENT
7 VPOS -3.262E-03 VNEG 3.657E-03 TOTAL POWER = 104 MW (ONE CHANNEL)

8
9

10 ----- ZENER DIODE -----

11 NAME: DZ1 MODEL: DZR

13 ID=-2.294E-04 VD=-5.989E+00 RES= 1.127E-12 CAP= 1.341E-12

15
16

16 ----- BJT'S -----

17 NAME: Q1 MODEL: RPO

19 IB=-8.220E-07 IC=-6.591E-05 VBE=-1.100E+00 VBC= 1.049E+01
20 VCE=-1.159E+01 BETAAC= 8.018E+01 GM= 2.538E-03 RPI= 3.321E+01
21 RO= 1.019E+06 CPI= 1.679E-12 CMU= 2.181E-13 BETAAC= 8.430E+01
22 FT= 2.130E+08

24
25

25 NAME: Q2 MODEL: RPO

27 IB=-8.211E-07 IC=-6.590E-05 VBE=-1.100E+00 VBC= 1.056E+01
28 VCE=-1.166E+01 BETAAC= 8.026E+01 GM= 2.538E-03 RPI= 3.325E+01
29 RO= 1.020E+06 CPI= 1.678E-12 CMU= 2.177E-13 BETAAC= 8.438E+01
30 FT= 2.131E+08

31
32

32 NAME: Q3 MODEL: RNO

34 IB= 3.579E-07 IC= 4.744E-05 VBE= 1.042E+00 VBC=-1.166E+01
35 VCE= 1.274E+01 BETAAC= 1.325E+02 GM= 1.328E-03 RPI= 3.241E+01
36 RO= 1.741E+06 CPI= 1.066E-12 CMU= 2.895E-13 BETAAC= 1.507E+02
37 FT= 2.147E+08

38
39

39 NAME: Q4 MODEL: RN1

41 IB= 5.837E-07 IC= 6.556E-05 VBE= 1.076E+00 VBC=-1.153E+01
42 VCE= 2.229E+00 BETAAC= 1.123E+02 GM= 2.527E-03 RPI= 5.119E+01
43 RO= 1.100E+06 CPI= 1.341E-12 CMU= 6.451E-13 BETAAC= 1.294E+02
44 FT= 1.592E+08

45
46

46 NAME: Q5 MODEL: RN1

48 IB= 5.840E-07 IC= 6.554E-05 VBE= 1.076E+00 VBC=-1.042E+01
49 VCE= 2.154E+00 BETAAC= 1.122E+02 GM= 2.524E-03 RPI= 5.115E+01
50 RO= 1.099E+06 CPI= 1.341E-12 CMU= 6.507E-13 BETAAC= 1.292E+02
51 FT= 1.593E+08

53
54

53 NAME: Q6 MODEL: RN1

55 IB= 2.459E-07 IC= 2.331E-05 VBE= 1.049E+00 VBC=-7.581E+01


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36 VCF= 1.808E+00 BETADC= 9.481E+01 GM= 8.994E-04 RPI= 1.299E+0
57 RO= 3.080E+06 CPI= 1.622E-12 CMU= 6.787E-13 BETAAC= 1.169E+0
58 FT= 6.221E+07
59
60 NAME: Q7 MODEL: RN1
61
62 IB= 2.459E-07 IC= 2.331E-05 VBE= 1.049E+00 VBC=-7.581E-0
63 VCE= 1.808E+00 BETADC= 9.481E+01 GM= 8.994E-04 RPI= 1.299E+0
64 RO= 3.080E+06 CPI= 1.622E-12 CMU= 6.787E-13 BETAAC= 1.169E+0
65 FT= 6.221E+07
66
67 NAME: Q8 MODEL: RPO
68
69 IB=-1.551E-06 IC=-1.335E-04 VBE=-1.117E+00 VBC= 1.350E+0
70 VCE=-1.462E+01 BETADC= 8.602E+01 GM= 5.129E-03 RPI= 1.734E+0
71 RO= 5.248E+05 CPI= 2.440E-12 CMU= 2.016E-13 BETAAC= 8.895E+0
72 FT= 3.090E+08
73
74 NAME: Q9 MODEL: RPI
75
76 IB=-3.828E-06 IC=-2.724E-04 VBE=-1.123E+00 VBC= 1.079E+0
77 VCE=-2.202E+00 BETADC= 7.116E+01 GM= 1.045E-02 RPI= 7.002E+0
78 RO= 2.112E+05 CPI= 5.489E-12 CMU= 6.135E-13 BETAAC= 7.320E+0
79 FT= 2.727E+08
80
81 NAME: Q10 MODEL: RPI
82
83 IB=-7.733E-07 IC=-6.080E-05 VBE=-1.079E+00 VBC= 1.243E+0
84 VCE=-1.351E+01 BETADC= 7.861E+01 GM= 2.345E-03 RPI= 3.614E+0
85 RO= 1.137E+06 CPI= 2.307E-12 CMU= 2.961E-13 BETAAC= 8.473E+0
86 FT= 1.433E+08
87
88 NAME: Q11 MODEL: RNO
89
90 IB= 1.663E-06 IC= 2.732E-04 VBE= 1.126E+00 VBC=-1.806E+0
91 VCE= 1.919E+01 BETADC= 1.643E+02 GM= 1.045E-02 RPI= 1.658E+0
92 RO= 3.246E+05 CPI= 2.113E-12 CMU= 2.655E-13 BETAAC= 1.733E+0
93 FT= 6.993E+08
94
95 NAME: Q12 MODEL: RNO
96
97 IB= 3.486E-07 IC= 4.600E-05 VBE= 1.081E+00 VBC=-1.159E+0
98 VCE= 1.267E+01 BETADC= 1.320E+02 GM= 1.773E-03 RPI= 8.475E+0
99 RO= 1.794E+06 CPI= 1.058E-12 CMU= 2.899E-13 BETAAC= 1.502E+0
100 FT= 2.093E+08
101
102 NAME: Q13 MODEL: RN1
103
104 IB= 4.217E-07 IC= 4.470E-05 VBE= 1.066E+00 VBC=-8.294E-0
105 VCF= 1.896E+00 BETADC= 1.060E+02 GM= 1.724E-03 RPI= 7.247E+0
106 RO= 1.607E+06 CPI= 1.757E-12 CMU= 6.724E-13 BETAAC= 1.249E+0
107 FT= 1.129E+08
108
109 NAME: Q14 MODEL: RN1
110

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111	IB= 2.124E-04	IC= 2.744E-04	VBF= 1.114E+00	VBC= -1.069E+00
112	VCE= 2.143E+00	BETADC= 1.292E+02	GM= 1.053E-02	RPI= 1.317E+00
113	RO= 2.616E+05	CPI= 3.102E-12	CMU= 6.590E-13	BETAAC= 1.387E+00
114	FT= 4.457E+08			
115				
116	NAME: Q15	MODEL: RP0		
117				
118	IB= -2.745E-06	IC= -2.358E-04	VBF= -1.133E+00	VBC= 1.240E+00
119	VCE= -1.353E+01	BETADC= 8.589E+01	GM= 9.030E-03	RPI= 9.707E+00
120	RO= 2.918E+05	CPI= 3.698E-12	CMU= 2.077E-13	BETAAC= 8.765E+00
121	FT= 3.640E+08			
122				
123	NAME: Q16	MODEL: RN1LC		
124				
125	IB= 1.829E-06	IC= 2.302E-04	VBF= 1.110E+00	VBC= 0.000E+00
126	VCE= 1.110E+00	BETADC= 1.259E+02	GM= 8.841E-03	RPI= 1.539E+00
127	RO= 3.075E+05	CPI= 2.864E-12	CMU= 8.156E-13	BETAAC= 1.361E+00
128	FT= 3.824E+08			
129				
130	NAME: Q17	MODEL: RP1LC		
131				
132	IB= -3.245E-06	IC= -2.287E-04	VBF= -1.119E+00	VBC= 0.000E+00
133	VCE= -1.119E+00	BETADC= 6.963E+01	GM= 8.745E-03	RPI= 8.182E+00
134	RO= 2.474E+05	CPI= 4.918E-12	CMU= 9.015E-13	BETAAC= 7.188E+00
135	FT= 2.402E+08			
136				
137	NAME: Q18	MODEL: RN1		
138				
139	IB= 4.562E-07	IC= 5.695E-05	VBF= 1.069E+00	VBC= -1.243E+00
140	VCE= 1.350E+01	BETADC= 1.248E+02	GM= 2.196E-03	RPI= 6.661E+00
141	RO= 1.465E+06	CPI= 1.783E-12	CMU= 4.234E-13	BETAAC= 1.463E+00
142	FT= 1.584E+08			
143				
144	NAME: Q19	MODEL: RN1		
145				
146	IB= 1.644E-06	IC= 2.384E-04	VBF= 1.107E+00	VBC= -1.155E+00
147	VCE= 1.266E+01	BETADC= 1.450E+02	GM= 9.163E-03	RPI= 1.720E+00
148	RO= 3.453E+05	CPI= 2.716E-12	CMU= 4.302E-13	BETAAC= 1.576E+00
149	FT= 4.635E+08			
150				
151	NAME: Q20	MODEL: RN1LC		
152				
153	IB= 1.887E-06	IC= 2.381E-04	VBF= 1.110E+00	VBC= 0.000E+00
154	VCE= 1.110E+00	BETADC= 1.262E+02	GM= 9.145E-03	RPI= 1.490E+00
155	RO= 2.972E+05	CPI= 2.911E-12	CMU= 8.162E-13	BETAAC= 1.362E+00
156	FT= 3.905E+08			
157				
158	NAME: Q21	MODEL: RN4		
159				
160	IB= 3.798E-06	IC= 5.356E-04	VBF= 1.091E+00	VBC= -1.387E+00
161	VCE= 1.496E+01	BETADC= 1.410E+02	GM= 2.063E-02	RPI= 7.643E+00
162	RO= 1.582E+05	CPI= 8.515E-12	CMU= 1.191E-12	BETAAC= 1.577E+00
163	FT= 3.383E+08			
164				
165	NAME: Q22	MODEL: RP4		

166
167 IB=-6.364E-06 IC=-5.347E-04 VBE=-1.099E+00 VBC= 1.346E+0
168 VCE=-1.496E+01 BETADC= 8.403E+01 GM= 2.060E-02 RPI= 4.293E+0
169 RO= 1.318E+05 CPI= 1.243E-11 CMU= 8.324E-13 BETAAC= 8.843E+0
170 FT= 2.472E+08
171
172 NAME: Q23 MODEL: RN1LC
173
174 IB= 5.918E-07 IC= 6.555E-05 VBE= 1.077E+00 VBC= 0.000E+0
175 VCE= 1.077E+00 BETADC= 1.108E+02 GM= 2.527E-03 RPI= 5.044E+0
176 RO= 1.082E+06 CPI= 1.887E-12 CMU= 8.043E-13 BETAAC= 1.275E+0
177 FT= 1.494E+08
178
179 NAME: Q24 MODEL: RN1LC
180
181 IB= 5.916E-07 IC= 6.554E-05 VBE= 1.077E+00 VBC= 0.000E+0
182 VCE= 1.077E+00 BETADC= 1.108E+02 GM= 2.526E-03 RPI= 5.046E+0
183 RO= 1.083E+06 CPI= 1.887E-12 CMU= 8.043E-13 BETAAC= 1.274E+0
184 FT= 1.494E+08
185
186 NAME: Q25 MODEL: RN1LC
187
188 IB= 4.924E-07 IC= 5.298E-05 VBE= 1.071E+00 VBC= 0.000E+0
189 VCE= 1.071E+00 BETADC= 1.076E+02 GM= 2.043E-03 RPI= 6.138E+0
190 RO= 1.339E+06 CPI= 1.811E-12 CMU= 8.034E-13 BETAAC= 1.254E+0
191 FT= 1.244E+08
192
193 NAME: Q26 MODEL: RP1LC
194
195 IB=-8.127E-07 IC=-5.263E-05 VBE=-1.080E+00 VBC= 0.000E+0
196 VCE=-1.080E+00 BETADC= 6.476E+01 GM= 2.029E-03 RPI= 3.433E+0
197 RO= 1.078E+06 CPI= 2.347E-12 CMU= 8.689E-13 BETAAC= 6.965E+0
198 FT= 1.004E+08
199
200 NAME: Q27 MODEL: RN1LC
201
202 IB= 1.810E-06 IC= 2.276E-04 VBE= 1.109E+00 VBC= 0.000E+0
203 VCE= 1.109E+00 BETADC= 1.258E+02 GM= 8.744E-03 RPI= 1.556E+0
204 RO= 3.110E+05 CPI= 2.849E-12 CMU= 8.154E-13 BETAAC= 1.360E+0
205 FT= 3.798E+08
206
207 NAME: Q28 MODEL: RN1LC
208
209 IB= 1.810E-06 IC= 2.276E-04 VBE= 1.109E+00 VBC= 0.000E+0
210 VCE= 1.109E+00 BETADC= 1.258E+02 GM= 8.744E-03 RPI= 1.556E+0
211 RO= 3.110E+05 CPI= 2.849E-12 CMU= 8.154E-13 BETAAC= 1.360E+0
212 FT= 3.798E+08
213
214 NAME: Q29 MODEL: RN1LC
215
216 IB= 1.810E-06 IC= 2.276E-04 VBE= 1.109E+00 VBC= 0.000E+0
217 VCE= 1.109E+00 BETADC= 1.258E+02 GM= 8.744E-03 RPI= 1.556E+0
218 RO= 3.110E+05 CPI= 2.849E-12 CMU= 8.154E-13 BETAAC= 1.360E+0
219 FT= 3.798E+08
220

221	NAME: Q30		MODEL: RNO	
222				
223	IB=-1.145E-16	IC= 1.145E-16	VBE= 0.000E+00	VBC=-1.047E+0
224	VCF= 1.047E+01	BFTADC=-1.000E+00	GM=-7.481E-22	RPI= 7.138E+1
225	RO= 6.930E+20	CPI= 4.500E-13	CMU= 2.956E-13	BETAAC=-5.340E-0
226	FT=-1.597E-10			
227				
228	NAME: Q31		MODEL: RNO	
229				
230	IB= 4.245E-07	IC= 5.985E-05	VBE= 1.087E+00	VBC=-1.497E+0
231	VCE= 1.606E+01	BETAADC= 1.410E+02	GM= 2.306E-03	RPI= 6.879E+0
232	RO= 1.435E+06	CPI= 1.118E-12	CMU= 2.754E-13	BETAAC= 1.586E+0
233	FT= 2.634E+08			
234				
235	NAME: Q32		MODEL: RNO	
236				
237	IB= 4.246E-07	IC= 5.985E-05	VBE= 1.087E+00	VBC=-1.497E+0
238	VCE= 1.606E+01	BETAADC= 1.410E+02	GM= 2.306E-03	RPI= 6.879E+0
239	RO= 1.435E+06	CPI= 1.118E-12	CMU= 2.754E-13	BETAAC= 1.586E+0
240	FT= 2.634E+08			
241				
242	NAME: Q33		MODEL: RNO	
243				
244	IB= 4.443E-07	IC= 6.110E-05	VBE= 1.089E+00	VBC=-1.240E+0
245	VCE= 1.349E+01	BETAADC= 1.375E+02	GM= 2.354E-03	RPI= 6.557E+0
246	RO= 1.363E+06	CPI= 1.133E-12	CMU= 2.860E-13	BETAAC= 1.543E+0
247	FT= 2.639E+08			
248				
249	NAME: Q34		MODEL: RNO	
250				
251	IB= 4.443E-07	IC= 6.110E-05	VBE= 1.089E+00	VBC=-1.240E+0
252	VCE= 1.349E+01	BETAADC= 1.375E+02	GM= 2.354E-03	RPI= 6.557E+0
253	RO= 1.363E+06	CPI= 1.133E-12	CMU= 2.860E-13	BETAAC= 1.543E+0
254	FT= 2.639E+08			
255				
256	NAME: Q35		MODEL: RPO	
257				
258	IB= 1.115E-17	IC=-1.115E-17	VBE= 0.000E+00	VBC= 1.457E+0
259	VCE=-1.457E+00	BETAADC=-1.000E+00	GM=-7.669E-23	RPI= 1.020E+1
260	RO= 1.208E+21	CPI= 5.200E-13	CMU= 3.843E-13	BETAAC=-7.821E-0
261	FT=-1.350E-11			
262				
263	NAME: Q36		MODEL: RPI	
264				
265	IB= 2.230E-17	IC=-2.230E-17	VBE= 0.000E+00	VBC= 1.457E+0
266	VCF=-1.457E+00	BETAADC=-1.000E+00	GM=-1.534E-22	RPI= 5.099E+1
267	RO= 6.039E+20	CPI= 9.500E-13	CMU= 5.509E-13	BETAAC=-7.821E-0
268	FT=-1.626E-11			
269				
270	NAME: Q37		MODEL: RPO	
271				
272	IB= 1.115E-17	IC=-1.115E-17	VBE= 0.000E+00	VBC= 1.457E+0
273	VCE=-1.457E+00	BETAADC=-1.000E+00	GM=-7.669E-23	RPI= 1.020E+1
274	RO= 1.208E+21	CPI= 5.200E-13	CMU= 3.843E-13	BETAAC=-7.821E-0
275	FT=-1.350E-11			

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276
277 NAME: Q38 MODEL: RN1
278
279 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
280 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
281 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
282 FT=-2.282E-11
283
284 NAME: Q39 MODEL: RN1
285
286 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
287 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
288 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
289 FT=-2.282E-11
290
291 NAME: Q40 MODEL: PN1
292
293 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
294 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
295 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
296 FT=-2.282E-11
297
298 NAME: Q41 MODEL: RN1
299
300 IB=-3.167E-17 IC= 3.167E-17 VBE= 0.000E+00 VBC=-1.448E+0
301 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-2.069E-22 RPI= 3.569E+1
302 RO= 4.268E+20 CPI= 8.200E-13 CMU= 6.227E-13 BETAAC=-7.384E-0
303 FT=-2.282E-11
304
305 NAME: Q42 MODEL: RP0
306
307 IB= 1.144E-16 IC=-1.144E-16 VBE= 0.000E+00 VBC= 1.495E+0
308 VCE=-1.495E+01 BETADC=-1.000E+00 GM=-7.869E-22 RPI= 1.020E+1
309 RO= 8.453E+20 CPI= 5.200E-13 CMU= 1.946E-13 BETAAC=-8.025E-0
310 FT=-1.753E-10
311
312 NAME: Q43 MODEL: RN4
313
314 IB=-1.949E-16 IC= 1.950E-16 VBE= 0.000E+00 VBC=-2.228E+0
315 VCE= 2.228E+00 BETADC=-1.000E+00 GM=-1.274E-21 RPI= 8.923E+1
316 RO= 1.046E+20 CPI= 3.200E-12 CMU= 1.674E-12 BETAAC=-1.136E-0
317 FT=-4.159E-11
318
319 NAME: Q44 MODEL: RN0
320
321 IB=-3.673E-17 IC= 3.673E-17 VBE= 0.000E+00 VBC=-3.359E+0
322 VCE= 3.359E+00 BETADC=-1.000E+00 GM=-2.400E-22 RPI= 7.138E+1
323 RO= 8.137E+20 CPI= 4.500E-13 CMU= 3.665E-13 BETAAC=-1.713E-0
324 FT=-4.677E-11
325
326 NAME: Q45 MODEL: RN0
327
328 IB=-1.583E-17 IC= 1.584E-17 VBE= 0.000E+00 VBC=-1.448E+0
329 VCE= 1.448E+00 BETADC=-1.000E+00 GM=-1.034E-22 RPI= 7.138E+1
330 RO= 8.536E+20 CPI= 4.500E-13 CMU= 4.203E-13 BETAAC=-7.384E-0

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331      FT=-1.892E-11
332
333  NAME:  Q46      MODEL:  RN0
334
335      IB=-1.5A3E-17      IC= 1.5A4E-17      VBE= 0.000E+00      VBC=-1.448E+0
336      VCE= 1.448E+00      BETADC=-1.000E+00      GM=-1.034E-22      RPI= 7.138E+1
337      RO= 8.536E+20      CPI= 4.500E-13      CMU= 4.203E-13      BETAAC=-7.3A4E-0
338      FT=-1.892E-11
339
340  NAME:  Q47      MODEL:  RP0
341
342      IB=-2.110E-06      IC=-1.779E-04      VBE=-1.125E+00      VBC= 1.153E+0
343      VCE=-1.266E+01      BETADC= 8.434E+01      GM= 6.827E-03      RPI= 1.268E+0
344      RO= 3.820E+05      CPI= 3.027E-12      CMU= 2.123E-13      BETAAC= 8.659E+0
345      FT= 3.354E+08
346
347  NAME:  Q48      MODEL:  RP0
348
349      IB=-2.110E-06      IC=-1.7A0E-04      VBE=-1.125E+00      VBC= 1.152E+0
350      VCE=-1.264E+01      BETADC= 8.433E+01      GM= 6.828E-03      RPI= 1.268E+0
351      RO= 3.820E+05      CPI= 3.028E-12      CMU= 2.123E-13      BETAAC= 8.657E+0
352      FT= 3.354E+08
353
354  NAME:  Q49      MODEL:  RN0
355
356      IB= 3.695E-07      IC= 4.910E-05      VBE= 1.0A3E+00      VBC=-1.152E+0
357      VCE= 1.260E+01      BETADC= 1.329E+02      GM= 1.892E-03      RPI= 7.968E+0
358      RO= 1.679E+06      CPI= 1.075E-12      CMU= 2.902E-13      BETAAC= 1.508E+0
359      FT= 2.206E+08
360
361  NAME:  Q50      MODEL:  RN1
362
363      IB= 1.421E-06      IC= 1.776E-04      VBE= 1.102E+00      VBC=-1.071E+0
364      VCE= 2.173E+00      BETADC= 1.249E+02      GM= 6.829E-03      RPI= 2.002E+0
365      RO= 4.047E+05      CPI= 2.539E-12      CMU= 6.554E-13      BETAAC= 1.367E+0
366      FT= 3.403E+08
367
368  NAME:  Q51      MODEL:  RN1
369
370      IB= 1.421E-06      IC= 1.776E-04      VBE= 1.102E+00      VBC=-1.0A3E+0
371      VCE= 2.186E+00      BETADC= 1.250E+02      GM= 6.829E-03      RPI= 2.002E+0
372      RO= 4.047E+05      CPI= 2.539E-12      CMU= 6.544E-13      BETAAC= 1.367E+0
373      FT= 3.404E+08
374
375  NAME:  Q52      MODEL:  RN1
376
377      IB= 2.456E-07      IC= 2.331E-05      VBE= 1.049E+00      VBC=-8.444E-0
378      VCE= 1.894E+00      BETADC= 9.490E+01      GM= 8.993E-04      RPI= 1.301E+0
379      RO= 3.0A4E+06      CPI= 1.622E-12      CMU= 6.701E-13      BETAAC= 1.170E+0
380      FT= 6.244E+07
381
382  NAME:  Q53      MODEL:  RN1
383
384      IB= 2.456E-07      IC= 2.331E-05      VBE= 1.049E+00      VBC=-8.444E-0
385      VCE= 1.894E+00      BETADC= 9.490E+01      GM= 8.993E-04      RPI= 1.301E+0

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386	RO= 3.084E+06	CPI= 1.622E-12	CMU= 6.701E-13	BETAAC= 1.170E+0
387	FT= 6.244E+07			
388				
389	NAME: Q54	MODEL: RP0		
390				
391	IB=-4.193E-06	IC=-3.601E-04	VBE=-1.144E+00	VBC= 1.204E+0
392	VCE=-1.318E+01	BETAOC= 8.549E+01	GM= 1.373E-02	RPI= 6.320E+0
393	RO= 1.897E+05	CPI= 5.232E-12	CMU= 2.102E-13	BETAAC= 8.677E+0
394	FT= 4.016E+08			
395				
396	NAME: Q55	MODEL: RP1		
397				
398	IB=-4.416E-06	IC=-3.154E-04	VBE=-1.127E+00	VBC= 1.088E+0
399	VCE=-2.215E+00	BETAOC= 7.142E+01	GM= 1.209E-02	RPI= 6.054E+0
400	RO= 8.120E+05	CPI= 6.108E-12	CMU= 6.160E-13	BETAAC= 7.322E+0
401	FT= 2.863E+08			
402				
403	NAME: Q56	MODEL: RP1		
404				
405	IB=-1.059E-06	IC=-8.490E-05	VBE=-1.088E+00	VBC= 1.226E+0
406	VCE=-1.334E+01	BETAOC= 8.020E+01	GM= 3.273E-03	RPI= 2.612E+0
407	RO= 8.120E+05	CPI= 2.600E-12	CMU= 2.976E-13	BETAAC= 8.547E+0
408	FT= 1.798E+08			
409				
410	NAME: Q57	MODEL: RN0		
411				
412	IB= 1.916E-06	IC= 3.165E-04	VBE= 1.130E+00	VBC=-1.789E+0
413	VCE= 1.902E+01	BETAOC= 1.652E+02	GM= 1.209E-02	RPI= 1.432E+0
414	RO= 2.795E+05	CPI= 2.321E-12	CMU= 2.661E-13	BETAAC= 1.732E+0
415	FT= 7.439E+08			
416				
417	NAME: Q58	MODEL: RN0		
418				
419	IB= 3.526E-07	IC= 4.657E-05	VBE= 1.082E+00	VBC=-1.153E+0
420	VCE= 1.261E+01	BETAOC= 1.321E+02	GM= 1.795E-03	RPI= 8.372E+0
421	RO= 1.770E+06	CPI= 1.062E-12	CMU= 2.902E-13	BETAAC= 1.503E+0
422	FT= 2.113E+08			
423				
424	NAME: Q59	MODEL: RN1		
425				
426	IB= 4.235E-07	IC= 4.493E-05	VBE= 1.066E+00	VBC=-8.333E+0
427	VCE= 1.900E+00	BETAOC= 1.061E+02	GM= 1.732E-03	RPI= 7.214E+0
428	RO= 1.598E+06	CPI= 1.758E-12	CMU= 6.720E-13	BETAAC= 1.250E+0
429	FT= 1.135E+08			
430				
431	NAME: Q60	MODEL: RN1		
432				
433	IB= 2.438E-06	IC= 3.179E-04	VBE= 1.118E+00	VBC=-1.072E+0
434	VCE= 2.190E+00	BETAOC= 1.304E+02	GM= 1.219E-02	RPI= 1.142E+0
435	RO= 2.257E+05	CPI= 3.354E-12	CMU= 6.604E-13	BETAAC= 1.392E+0
436	FT= 4.832E+08			
437				
438	NAME: Q61	MODEL: RP0		
439				
440	IB=-3.369E-06	IC=-2.895E-04	VBE=-1.138E+00	VBC= 1.223E+0

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441 VCE=-1.337E+01 BETADC= 8.595E+01 GM= 1.107E-02 RPI= 7.888E+0
442 RO= 2.368E+05 CPI= 4.357E-12 CMU= 2.048E-13 BETAAC= 8.729E+0
443 FT= 3.857E+08
444
445 NAME: Q62 MODEL: RN1LC
446
447 IB= 2.202E-06 IC= 2.811E-04 VBE= 1.115E+00 VBC= 0.000E+0
448 VCE= 1.115E+00 BETADC= 1.277E+02 GM= 1.079E-02 RPI= 1.269E+0
449 RO= 2.517E+05 CPI= 3.164E-12 CMU= 8.193E-13 BETAAC= 1.369E+0
450 FT= 4.310E+08
451
452 NAME: Q63 MODEL: RP1LC
453
454 IB=-3.990E-06 IC=-2.794E-04 VBE=-1.124E+00 VBC= 0.000E+0
455 VCE=-1.124E+00 BETADC= 7.002E+01 GM= 1.072E-02 RPI= 6.713E+0
456 RO= 2.024E+05 CPI= 5.659E-12 CMU= 9.119E-13 BETAAC= 7.195E+0
457 FT= 2.596E+08
458
459 NAME: Q64 MODEL: RN1
460
461 IB= 5.039E-07 IC= 6.390E-05 VBE= 1.072E+00 VBC=-1.237E+0
462 VCE= 1.344E+01 BETADC= 1.268E+02 GM= 2.464E-03 RPI= 5.949E+0
463 RO= 1.304E+06 CPI= 1.820E-12 CMU= 4.238E-13 BETAAC= 1.476E+0
464 FT= 1.748E+08
465
466 NAME: Q65 MODEL: RN1
467
468 IB= 1.994E-06 IC= 2.936E-04 VBE= 1.112E+00 VBC=-1.149E+0
469 VCE= 1.260E+01 BETADC= 1.472E+02 GM= 1.127E-02 RPI= 1.407E+0
470 RO= 2.800E+05 CPI= 2.997E-12 CMU= 4.309E-13 BETAAC= 1.586E+0
471 FT= 5.234E+08
472
473 NAME: Q66 MODEL: RN1LC
474
475 IB= 2.291E-06 IC= 2.933E-04 VBE= 1.116E+00 VBC= 0.000E+0
476 VCE= 1.116E+00 BETADC= 1.280E+02 GM= 1.125E-02 RPI= 1.218E+0
477 RO= 2.412E+05 CPI= 3.236E-12 CMU= 8.202E-13 BETAAC= 1.371E+0
478 FT= 4.414E+08
479
480 NAME: Q67 MODEL: RNAC
481
482 IB= 6.197E-06 IC= 8.519E-04 VBE= 1.085E+00 VBC=-1.345E+0
483 VCE= 1.493E+01 BETADC= 1.375E+02 GM= 3.283E-02 RPI= 4.738E+0
484 RO= 9.946E+04 CPI= 1.557E-11 CMU= 1.969E-12 BETAAC= 1.555E+0
485 FT= 2.980E+08
486
487 NAME: Q68 MODEL: RPRC
488
489 IB=-1.022E-05 IC=-8.479E-04 VBE=-1.093E+00 VBC= 1.384E+0
490 VCE=-1.493E+01 BETADC= 8.300E+01 GM= 3.268E-02 RPI= 2.691E+0
491 RO= 8.315E+04 CPI= 2.209E-11 CMU= 1.332E-12 BETAAC= 8.793E+0
492 FT= 2.220E+08
493
494 NAME: Q69 MODEL: RN1LC
495

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496	IR= 1.440E-06	IC= 1.776E-04	VBE= 1.103E+00	VBC= 0.000E+0
497	VCE= 1.103E+00	BETAOC= 1.233E+02	GM= 6.828E-03	RPI= 1.974E+0
498	RO= 3.9A8E+05	CPI= 2.554E-12	CMU= 8.119E-13	BETAAC= 1.348E+0
499	FT= 3.229E+08			
500				
501	NAME: Q70	MODEL: RN1LC		
502				
503	IR= 1.440E-06	IC= 1.776E-04	VBE= 1.103E+00	VBC= 0.000E+0
504	VCE= 1.103E+00	BETAOC= 1.233E+02	GM= 6.828E-03	RPI= 1.974E+0
505	RO= 3.9A8E+05	CPI= 2.554E-12	CMU= 8.119E-13	BETAAC= 1.348E+0
506	FT= 3.229E+08			
507				
508	NAME: Q71	MODEL: RN1LC		
509				
510	IR= 5.520E-07	IC= 6.050E-05	VBE= 1.075E+00	VBC= 0.000E+0
511	VCE= 1.075E+00	BETAOC= 1.096E+02	GM= 2.332E-03	RPI= 5.433E+0
512	RO= 1.173E+06	CPI= 1.857E-12	CMU= 8.039E-13	BETAAC= 1.267E+0
513	FT= 1.395E+08			
514				
515	NAME: Q72	MODEL: RP1LC		
516				
517	IR=-1.102E-06	IC=-7.288E-05	VBE=-1.089E+00	VBC= 0.000E+0
518	VCE=-1.089E+00	BETAOC= 6.615E+01	GM= 2.808E-03	RPI= 2.506E+0
519	RO= 7.782E+05	CPI= 2.644E-12	CMU= 8.724E-13	BETAAC= 7.038E+0
520	FT= 1.271E+08			
521				
522	NAME: Q73	MODEL: RN0		
523				
524	IR=-1.138E-16	IC= 1.138E-16	VBE= 0.000E+00	VBC=-1.041E+0
525	VCE= 1.041E+01	BETAOC=-1.000E+00	GM=-7.434E-22	RPI= 7.138E+1
526	RO= 6.940E+20	CPI= 4.500E-13	CMU= 2.960E-13	BETAAC=-5.307E-0
527	FT=-1.586E-10			
528				
529	NAME: Q74	MODEL: RN1		
530				
531	IR=-3.290E-16	IC= 3.270E-16	VBE=-7.107E-04	VBC=-1.495E+0
532	VCE= 1.495E+01	BETAOC=-9.441E-01	GM=-2.136E-21	RPI= 3.569E+1
533	RO= 3.169E+20	CPI= 8.198E-13	CMU= 4.078E-13	BETAAC=-7.625E-0
534	FT=-2.770E-10			
535				
536	NAME: Q75	MODEL: RP1		
537				
538	IR= 2.275E-16	IC=-2.289E-16	VBE=-7.107E-04	VBC= 1.495E+0
539	VCE=-1.495E+01	BETAOC=-1.006E+00	GM=-1.519E-21	RPI= 5.029E+1
540	RO= 4.226E+20	CPI= 9.502E-13	CMU= 2.790E-13	BETAAC=-7.639E-0
541	FT=-1.967E-10			
542				
543	NAME: Q76	MODEL: RP0		
544				
545	IR= 1.232E-17	IC=-1.233E-17	VBE= 0.000E+00	VBC= 1.610E+0
546	VCE=-1.610E+00	BETAOC=-1.000E+00	GM=-8.475E-23	RPI= 1.020E+1
547	RO= 1.202E+21	CPI= 5.200E-13	CMU= 3.749E-13	BETAAC=-8.643E-0
548	FT=-1.507E-11			
549				
550	NAME: Q77	MODEL: RP1		

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551
552      IB= 2.445E-17      IC=-2.465E-17      VBE= 0.000E+00      VBC= 1.610E+0
553      VCE=-1.610E+00      BETADC=-1.000E+00      GM=-1.695E-22      RPI= 5.099E+1
554      RO= 6.010E+20      CPI= 9.500E-13      CMU= 5.374E-13      BETAAC=-8.643E-0
555      FT=-1.814E-11
556
557      NAME:  Q7A      MODEL:  RP0
558
559      IB= 1.232E-17      IC=-1.233E-17      VBE= 0.000E+00      VBC= 1.610E+0
560      VCE=-1.610E+00      BETADC=-1.000E+00      GM=-8.475E-23      RPI= 1.020E+1
561      RO= 1.202E+21      CPI= 5.200E-13      CMU= 3.749E-13      BETAAC=-8.643E-0
562      FT=-1.507E-11
563
564      NAME:  Q79      MODEL:  RN1
565
566      IB=-3.291E-17      IC= 3.291E-17      VBE= 0.000E+00      VBC=-1.505E+0
567      VCE= 1.505E+00      BETADC=-1.000E+00      GM=-2.150E-22      RPI= 3.569E+1
568      RO= 4.262E+20      CPI= 8.200E-13      CMU= 6.191E-13      BETAAC=-7.674E-0
569      FT=-2.378E-11
570
571      NAME:  Q80      MODEL:  RN1
572
573      IB=-3.291E-17      IC= 3.291E-17      VBE= 0.000E+00      VBC=-1.505E+0
574      VCE= 1.505E+00      BETADC=-1.000E+00      GM=-2.150E-22      RPI= 3.569E+1
575      RO= 4.262E+20      CPI= 8.200E-13      CMU= 6.191E-13      BETAAC=-7.674E-0
576      FT=-2.378E-11
577
578      NAME:  Q81      MODEL:  RN1
579
580      IB=-3.291E-17      IC= 3.291E-17      VBE= 0.000E+00      VBC=-1.505E+0
581      VCE= 1.505E+00      BETADC=-1.000E+00      GM=-2.150E-22      RPI= 3.569E+1
582      RO= 4.262E+20      CPI= 8.200E-13      CMU= 6.191E-13      BETAAC=-7.674E-0
583      FT=-2.378E-11
584
585      NAME:  Q82      MODEL:  RN1
586
587      IB=-3.291E-17      IC= 3.291E-17      VBE= 0.000E+00      VBC=-1.505E+0
588      VCE= 1.505E+00      BETADC=-1.000E+00      GM=-2.150E-22      RPI= 3.569E+1
589      RO= 4.262E+20      CPI= 8.200E-13      CMU= 6.191E-13      BETAAC=-7.674E-0
590      FT=-2.378E-11
591
592      NAME:  Q83      MODEL:  RP0
593
594      IB= 1.244E-16      IC=-1.244E-16      VBE= 0.000E+00      VBC= 1.626E+0
595      VCE=-1.626E+01      BETADC=-1.000E+00      GM=-8.557E-22      RPI= 1.020E+1
596      RO= 8.214E+20      CPI= 5.200E-13      CMU= 1.895E-13      BETAAC=-8.726E-0
597      FT=-1.920E-10
598
599      NAME:  Q84      MODEL:  RN8C
600
601      IB=-3.917E-16      IC= 3.918E-16      VBE= 0.000E+00      VBC=-2.239E+0
602      VCE= 2.239E+00      BETADC=-1.000E+00      GM=-2.559E-21      RPI= 4.462E+1
603      RO= 5.229E+19      CPI= 6.200E-12      CMU= 2.764E-12      BETAAC=-1.142E-0
604      FT=-4.544E-11
605

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606	NAME: QAS	MODEL: RNO		
607				
608	IB=-3.740E-17	IC= 3.740E-17	VBF= 0.000E+00	VBC=-3.420E+0
609	VCF= 3.420E+00	BETADC=-1.000E+00	GM=-2.443E-22	RPI= 7.138E+1
610	RO= 8.125E+20	CPI= 4.500E-13	CMU= 3.653E-13	BETAAC=-1.744E-0
611	FT=-4.769E-11			

```

1 POST-RADIATION DINS PHOTOPREAMPLIFIER OPERATING POINTS
2
3 (TEMPERATURE 25 DEGREES C)
4
5 ----- VOLTAGE SUPPLY CURRENTS -----
6
7 NAME   CURRNT   NAME   CURRNT
8 VPOS   -3.161E-03 VNEG   3.567E-03   TOTAL POWER = 101 MW (ONE CHANNEL)
9
10
11 ----- ZENFR DIODE -----
12
13 NAME:  DZ1           MODEL:  DZR
14
15 ID=-2.569E-04   VD=-6.202E+00   REG= 1.000E+02   CAP= 1.605E-1
16
17 ----- BJT'S -----
18
19 NAME:  Q1           MODEL:  RP0
20
21 IR=-6.097E-06   IC=-6.015E-05   VBE=-6.625E-01   VBC= 1.213E+0
22 VCE=-1.279E+01  BETADC= 9.865E+00   GM= 2.334E-03    RPI= 5.030E+0
23 RO= 1.164E+06   CPI= 1.474E-12    CMII= 1.851E-13  BETAAC= 1.174E+0
24 FT= 2.239E+08
25
26 NAME:  Q2           MODEL:  RP0
27
28 IR=-6.079E-06   IC=-6.002E-05   VBE=-6.625E-01   VBC= 1.223E+0
29 VCE=-1.249E+01  BETADC= 9.874E+00   GM= 2.329E-03    RPI= 5.045E+0
30 RO= 1.653E+06   CPI= 1.472E-12    CMII= 1.846E-13  BETAAC= 1.175E+0
31 FT= 2.238E+08
32
33 NAME:  Q3           MODEL:  RN0
34
35 IR= 2.751E-06   IC= 5.160E-05   VBE= 6.493E-01   VBC=-1.296E+0
36 VCE= 1.361E+01  BETADC= 1.876E+01   GM= 2.003E-03    RPI= 1.150E+0
37 RO= 1.653E+06   CPI= 9.461E-13    CMII= 2.680E-13  BETAAC= 2.302E+0
38 FT= 2.625E+08
39
40 NAME:  Q4           MODEL:  RN1
41
42 IR= 3.870E-06   IC= 5.729E-05   VBE= 6.383E-01   VBC=-7.474E-0
43 VCE= 1.386E+00  BETADC= 1.480E+01   GM= 2.224E-03    RPI= 8.274E+0
44 RO= 1.278E+06   CPI= 1.583E-12    CMII= 6.744E-13  BETAAC= 1.840E+0
45 FT= 1.568E+08
46
47 NAME:  Q5           MODEL:  RN1
48
49 IR= 3.873E-06   IC= 5.727E-05   VBE= 6.383E-01   VBC=-6.493E-0
50 VCE= 1.288E+00  BETADC= 1.479E+01   GM= 2.223E-03    RPI= 8.267E+0
51 RO= 1.277E+06   CPI= 1.583E-12    CMII= 6.882E-13  BETAAC= 1.838E+0
52 FT= 1.558E+08
53
54 NAME:  Q6           MODEL:  RN1
55

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56	IR= 1.902E-06	IC= 2.331E-05	VBE= 6.147E-01	VBC=-2.876E-
57	VCE= 9.022E-01	BETADC= 1.226E+01	GM= 9.053E-04	RPI= 1.724E+
58	RO= 3.129E+06	CPI= 1.372E-12	CMU= 7.372E-13	BETAAC= 1.561E+
59	FT= 6.832E+07			
60				
61	NAME: Q7	MODEL: RN1		
62				
63	IR= 1.902E-06	IC= 2.331E-05	VBE= 6.147E-01	VBC=-2.876E-
64	VCE= 9.022E-01	BETADC= 1.226E+01	GM= 9.053E-04	RPI= 1.724E+
65	RO= 3.129E+06	CPI= 1.372E-12	CMU= 7.372E-13	BETAAC= 1.561E+
66	FT= 6.832E+07			
67				
68	NAME: Q8	MODEL: RP0		
69				
70	IR=-1.146E-05	IC=-1.323E-04	VBE=-6.839E-01	VBC= 1.398E+
71	VCE=-1.467E+01	BETADC= 1.135E+01	GM= 5.125E-03	RPI= 2.586E+
72	RO= 5.415E+05	CPI= 2.295E-12	CMU= 1.774E-13	BETAAC= 1.325E+
73	FT= 3.299E+08			
74				
75	NAME: Q9	MODEL: RP1		
76				
77	IR=-2.788E-05	IC=-2.647E-04	VBE=-6.928E-01	VBC= 6.595E-
78	VCE=-1.352E+00	BETADC= 9.495E+00	GM= 1.024E-02	RPI= 1.076E+
79	RO= 2.198E+05	CPI= 5.164E-12	CMU= 7.185E-13	BETAAC= 1.102E+
80	FT= 2.771E+08			
81				
82	NAME: Q10	MODEL: RP1		
83				
84	IR=-1.074E-05	IC=-1.050E-04	VBE=-6.595E-01	VBC= 1.325E+
85	VCE=-1.391E+01	BETADC= 9.777E+00	GM= 4.077E-03	RPI= 2.864E+
86	RO= 6.771E+05	CPI= 2.614E-12	CMU= 2.580E-13	BETAAC= 1.168E+
87	FT= 2.259E+08			
88				
89	NAME: Q11	MODEL: RN0		
90				
91	IR= 1.052E-05	IC= 2.755E-04	VBE= 6.938E-01	VBC=-1.995E+
92	VCE= 2.065E+01	BETADC= 2.618E+01	GM= 1.063E-02	RPI= 2.871E+
93	RO= 3.311E+05	CPI= 1.964E-12	CMU= 2.476E-13	BETAAC= 3.051E+
94	FT= 7.650E+08			
95				
96	NAME: Q12	MODEL: RN0		
97				
98	IR= 2.857E-06	IC= 5.399E-05	VBE= 6.506E-01	VBC=-1.287E+
99	VCE= 1.352E+01	BETADC= 1.890E+01	GM= 2.095E-03	RPI= 1.106E+
100	RO= 1.578E+06	CPI= 9.585E-13	CMU= 2.684E-13	BETAAC= 2.316E+
101	FT= 2.718E+08			
102				
103	NAME: Q13	MODEL: RN1		
104				
105	IR= 3.208E-06	IC= 4.513E-05	VBE= 6.321E-01	VBC=-3.844E-
106	VCE= 1.016E+00	BETADC= 1.407E+01	GM= 1.752E-03	RPI= 1.004E+
107	RO= 1.615E+06	CPI= 1.510E-12	CMU= 7.292E-13	BETAAC= 1.760E+
108	FT= 1.246E+08			
109				
110	NAME: Q14	MODEL: RN1		

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111
112 IR= 1.449E-05 IC= 2.815E-04 VBE= 6.830E-01 VBC=-6.433E-0
113 VCE= 1.326E+00 BETADC= 1.943E+01 GM= 1.089E-02 RPI= 2.112E+0
114 RO= 2.569E+05 CPI= 2.900E-12 CMU= 8.564E-13 BETAAC= 2.299E+0
115 FT= 4.613E+08
116
117 NAME: Q15 MODEL: RP0
118
119 IB=-1.932E-05 IC=-2.344E-04 VBE=-7.014E-01 VBC= 1.324E+0
120 VCE=-1.394E+01 BETADC= 1.213E+01 GM= 9.054E-03 RPI= 1.540E+0
121 RO= 3.014E+05 CPI= 3.517E-12 CMU= 1.816E-13 BETAAC= 1.395E+0
122 FT= 3.896E+08
123
124 NAME: Q16 MODEL: RN1LC
125
126 IR= 1.088E-05 IC= 1.997E-04 VBE= 6.731E-01 VBC= 0.000E+0
127 VCE= 6.731E-01 BETADC= 1.835E+01 GM= 7.733E-03 RPI= 2.840E+0
128 RO= 3.601E+05 CPI= 2.428E-12 CMU= 9.957E-13 BETAAC= 2.196E+0
129 FT= 3.595E+08
130
131 NAME: Q17 MODEL: RP1LC
132
133 IB=-2.106E-05 IC=-1.895E-04 VBE=-6.826E-01 VBC= 0.000E+0
134 VCE=-6.826E-01 BETADC= 9.001E+00 GM= 7.341E-03 RPI= 1.436E+0
135 RO= 3.051E+05 CPI= 4.110E-12 CMU= 1.013E-12 BETAAC= 1.054E+0
136 FT= 2.281E+08
137
138 NAME: Q18 MODEL: RN1
139
140 IB= 4.500E-06 IC= 8.084E-05 VBE= 6.433E-01 VBC=-1.326E+0
141 VCE= 1.390E+01 BETADC= 1.796E+01 GM= 3.138E-03 RPI= 7.077E+0
142 RO= 1.059E+06 CPI= 1.653E-12 CMU= 3.952E-13 BETAAC= 2.221E+0
143 FT= 2.438E+08
144
145 NAME: Q19 MODEL: RN1
146
147 IB= 1.171E-05 IC= 2.557E-04 VBE= 6.756E-01 VBC=-1.283E+0
148 VCE= 1.351E+01 BETADC= 2.184E+01 GM= 9.902E-03 RPI= 2.631E+0
149 RO= 3.308E+05 CPI= 2.535E-12 CMU= 4.010E-13 BETAAC= 2.605E+0
150 FT= 5.368E+08
151
152 NAME: Q20 MODEL: RN1LC
153
154 IB= 1.336E-05 IC= 2.541E-04 VBE= 6.801E-01 VBC= 0.000E+0
155 VCE= 6.801E-01 BETADC= 1.903E+01 GM= 9.831E-03 RPI= 2.301E+0
156 RO= 2.625E+05 CPI= 2.746E-12 CMU= 1.089E-12 BETAAC= 2.263E+0
157 FT= 4.080E+08
158
159 NAME: Q21 MODEL: RN4
160
161 IB= 2.384E-05 IC= 4.619E-04 VBE= 6.546E-01 VBC=-1.430E+0
162 VCE= 1.496E+01 BETADC= 1.938E+01 GM= 1.792E-02 RPI= 1.323E+0
163 RO= 1.874E+05 CPI= 7.161E-12 CMU= 1.120E-12 BETAAC= 2.371E+0
164 FT= 3.444E+08
165

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166 NAME: Q22 MODEL: RP4
167
168 IB=-4.513E-05 IC=-4.520E-04 VBE=-6.617E-01 VBC= 1.430E+0
169 VCE=-1.496E+01 BETAOC= 1.001E+01 GM= 1.754E-02 RPI= 6.808E+0
170 RO= 1.596E+05 CPI= 1.061E-11 CMII= 7.320E-13 BETAAC= 1.194E+0
171 FT= 2.462E+08
172
173 NAME: Q23 MODEL: RN1LC
174
175 IB= 3.897E-06 IC= 5.726E-05 VBE= 6.385E-01 VBC= 0.000E+0
176 VCE= 6.385E-01 BETAOC= 1.469E+01 GM= 2.223E-03 RPI= 8.213E+0
177 RO= 1.266E+06 CPI= 1.586E-12 CMII= 8.371E-13 BETAAC= 1.826E+0
178 FT= 1.460E+08
179
180 NAME: Q24 MODEL: RN1LC
181
182 IB= 3.896E-06 IC= 5.724E-05 VBE= 6.385E-01 VBC= 0.000E+0
183 VCE= 6.385E-01 BETAOC= 1.469E+01 GM= 2.222E-03 RPI= 8.215E+0
184 RO= 1.267E+06 CPI= 1.586E-12 CMII= 8.371E-13 BETAAC= 1.825E+0
185 FT= 1.460E+08
186
187 NAME: Q25 MODEL: RN1LC
188
189 IB= 3.698E-06 IC= 5.364E-05 VBE= 6.368E-01 VBC= 0.000E+0
190 VCE= 6.368E-01 BETAOC= 1.451E+01 GM= 2.082E-03 RPI= 8.672E+0
191 RO= 1.352E+06 CPI= 1.564E-12 CMII= 8.345E-13 BETAAC= 1.806E+0
192 FT= 1.382E+08
193
194 NAME: Q26 MODEL: RP1LC
195
196 IB=-6.876E-06 IC=-5.010E-05 VBE=-6.448E-01 VBC= 0.000E+0
197 VCE=-6.448E-01 BETAOC= 7.286E+00 GM= 1.945E-03 RPI= 4.528E+0
198 RO= 1.158E+06 CPI= 2.099E-12 CMII= 8.912E-13 BETAAC= 8.805E+0
199 FT= 1.035E+08
200
201 NAME: Q27 MODEL: RN1LC
202
203 IB= 1.290E-05 IC= 2.440E-04 VBE= 6.789E-01 VBC= 0.000E+0
204 VCE= 6.789E-01 BETAOC= 1.892E+01 GM= 9.441E-03 RPI= 2.385E+0
205 RO= 2.829E+05 CPI= 2.687E-12 CMII= 1.065E-12 BETAAC= 2.252E+0
206 FT= 4.005E+08
207
208 NAME: Q28 MODEL: RN1LC
209
210 IB= 1.290E-05 IC= 2.440E-04 VBE= 6.789E-01 VBC= 0.000E+0
211 VCE= 6.789E-01 BETAOC= 1.892E+01 GM= 9.441E-03 RPI= 2.385E+0
212 RO= 2.829E+05 CPI= 2.687E-12 CMII= 1.065E-12 BETAAC= 2.252E+0
213 FT= 4.005E+08
214
215 NAME: Q29 MODEL: RN1LC
216
217 IB= 1.290E-05 IC= 2.440E-04 VBE= 6.789E-01 VBC= 0.000E+0
218 VCE= 6.789E-01 BETAOC= 1.892E+01 GM= 9.441E-03 RPI= 2.385E+0
219 RO= 2.829E+05 CPI= 2.687E-12 CMII= 1.065E-12 BETAAC= 2.252E+0
220 FT= 4.005E+08

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221
222 NAME: Q30 MODEL: RNO
223
224 IB=-7.394F-11 IC= 7.422E-11 VBE= 0.000E+00 VBC=-1.218E+0
225 VCE= 1.218E+01 BETADC=-1.004E+00 GM=-1.502F-14 RPI= 8.237F+1
226 RO= 3.878E+13 CPI= 4.500E-13 CMU= 2.704E-13 BETAAC=-1.237E-0
227 FT=-3.318E-03
228
229 NAME: Q31 MODEL: RNO
230
231 IB= 2.800E-06 IC= 5.401E-05 VBE= 6.499E-01 VBC=-1.504E+0
232 VCE= 1.569E+01 BETADC= 1.929E+01 GM= 2.096E-03 RPI= 1.129E+0
233 RO= 1.618E+06 CPI= 9.518E-13 CMU= 2.599E-13 BETAAC= 2.366E+0
234 FT= 2.753E+08
235
236 NAME: Q32 MODEL: RNO
237
238 IB= 2.801E-06 IC= 5.402E-05 VBE= 6.499E-01 VBC=-1.504E+0
239 VCE= 1.569E+01 BETADC= 1.929E+01 GM= 2.097E-03 RPI= 1.129E+0
240 RO= 1.617E+06 CPI= 9.519E-13 CMU= 2.599E-13 BETAAC= 2.366E+0
241 FT= 2.754E+08
242
243 NAME: Q33 MODEL: RNO
244
245 IB= 3.229E-06 IC= 6.290E-05 VBE= 6.546E-01 VBC=-1.317E+0
246 VCE= 1.382E+01 BETADC= 1.948E+01 GM= 2.440E-03 RPI= 9.740E+0
247 RO= 1.358E+06 CPI= 1.003E-12 CMU= 2.673E-13 BETAAC= 2.377E+0
248 FT= 3.059E+08
249
250 NAME: Q34 MODEL: RNO
251
252 IB= 3.229E-06 IC= 6.290E-05 VBE= 6.546E-01 VBC=-1.317E+0
253 VCE= 1.382E+01 BETADC= 1.948E+01 GM= 2.440E-03 RPI= 9.740E+0
254 RO= 1.358E+06 CPI= 1.003E-12 CMU= 2.673E-13 BETAAC= 2.377E+0
255 FT= 3.059E+08
256
257 NAME: Q35 MODEL: RPO
258
259 IB= 4.435E-12 IC=-4.449E-12 VBE= 0.000E+00 VBC= 1.044E+0
260 VCE=-1.044E+00 BETADC=-1.003E+00 GM=-9.481E-16 RPI= 1.210E+1
261 RO= 7.094E+13 CPI= 5.200E-13 CMU= 3.803E-13 BETAAC=-1.147E-0
262 FT=-1.676E-04
263
264 NAME: Q36 MODEL: RPI
265
266 IB= 8.869F-12 IC=-8.898E-12 VBE= 0.000E+00 VBC= 1.044E+0
267 VCE=-1.044E+00 BETADC=-1.003E+00 GM=-1.896E-15 RPI= 6.048E+1
268 RO= 3.547E+13 CPI= 9.500E-13 CMU= 5.451E-13 BETAAC=-1.147E-0
269 FT=-2.019E-04
270
271 NAME: Q37 MODEL: RPO
272
273 IB= 4.435E-12 IC=-4.449E-12 VBE= 0.000E+00 VBC= 1.044E+0
274 VCE=-1.044E+00 BETADC=-1.003E+00 GM=-9.481E-16 RPI= 1.210E+1
275 RO= 7.094E+13 CPI= 5.200E-13 CMU= 3.803E-13 BETAAC=-1.147E-0

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276      FT=-1.676E-04
277
278  NAME:  Q38      MODEL:  RN1
279
280      IB=-1.260E-11      IC= 1.264E-11      VBE= 0.000E+00      VBC=-1.038E+
281      VCE= 1.038E+00      BETADC=-1.003E+00      GM=-2.559E-15      RPI= 4.119E+
282      RO= 2.500E+13      CPI= 8.200E-13      CMU= 6.263E-13      BETAAC=-1.054E-
283      FT=-2.816E-04
284
285  NAME:  Q39      MODEL:  RN1
286
287      IB=-1.260E-11      IC= 1.264E-11      VBE= 0.000E+00      VBC=-1.038E+
288      VCE= 1.038E+00      BETADC=-1.003E+00      GM=-2.559E-15      RPI= 4.119E+
289      RO= 2.500E+13      CPI= 8.200E-13      CMU= 6.263E-13      BETAAC=-1.054E-
290      FT=-2.816E-04
291
292  NAME:  Q40      MODEL:  RN1
293
294      IB=-1.260E-11      IC= 1.264E-11      VBE= 0.000E+00      VBC=-1.038E+
295      VCE= 1.038E+00      BETADC=-1.003E+00      GM=-2.559E-15      RPI= 4.119E+
296      RO= 2.500E+13      CPI= 8.200E-13      CMU= 6.263E-13      BETAAC=-1.054E-
297      FT=-2.816E-04
298
299  NAME:  Q41      MODEL:  RN1
300
301      IB=-1.260E-11      IC= 1.264E-11      VBE= 0.000E+00      VBC=-1.038E+
302      VCE= 1.038E+00      BETADC=-1.003E+00      GM=-2.559E-15      RPI= 4.119E+
303      RO= 2.500E+13      CPI= 8.200E-13      CMU= 6.263E-13      BETAAC=-1.054E-
304      FT=-2.816E-04
305
306  NAME:  Q42      MODEL:  RP0
307
308      IB= 6.316E-11      IC=-6.341E-11      VBE= 0.000E+00      VBC= 1.487E+
309      VCE=-1.487E+01      BETADC=-1.004E+00      GM=-1.350E-14      RPI= 1.210E+
310      RO= 4.908E+13      CPI= 5.200E-13      CMU= 1.728E-13      BETAAC=-1.633E-
311      FT=-3.102E-03
312
313  NAME:  Q43      MODEL:  RN4
314
315      IB=-6.582E-11      IC= 6.603E-11      VBE= 0.000E+00      VBC=-1.356E+
316      VCE= 1.356E+00      BETADC=-1.003E+00      GM=-1.337E-14      RPI= 1.030E+
317      RO= 6.190E+12      CPI= 3.200E-12      CMU= 1.730E-12      BETAAC=-1.376E-
318      FT=-4.316E-04
319
320  NAME:  Q44      MODEL:  RN0
321
322      IB=-1.258E-11      IC= 1.262E-11      VBE= 0.000E+00      VBC=-2.073E+
323      VCE= 2.073E+00      BETADC=-1.003E+00      GM=-2.555E-15      RPI= 8.237E+
324      RO= 4.869E+13      CPI= 4.500E-13      CMU= 3.788E-13      BETAAC=-2.105E-
325      FT=-4.907E-04
326
327  NAME:  Q45      MODEL:  RN0
328
329      IB=-6.301E-12      IC= 6.321E-12      VBE= 0.000E+00      VBC=-1.038E+
330      VCE= 1.038E+00      BETADC=-1.003E+00      GM=-1.280E-15      RPI= 8.237E+

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331      RO= 5.000E+13      CPI= 4.500E-13      CMU= 4.227E-13 BETAAC=-1.054E-0
332      FT=-2.334E-04
333
334  NAME:  Q46      MODEL:  RNO
335
336      IB=-6.301E-12      IC= 6.321E-12      VBE= 0.000E+00      VBC=-1.032E+0
337      VCE= 1.034E+00 BETAAC=-1.003E+00      GM=-1.220E-15      RPI= 8.237E+1
338      RO= 5.000E+13      CPI= 4.500E-13      CMU= 4.227E-13 BETAAC=-1.054E-0
339      FT=-2.334E-04
340
341  NAME:  Q47      MODEL:  RPO
342
343      IB=-1.420E-05      IC=-1.635E-04      VBE=-6.906E-01      VBC= 1.220E+0
344      VCE=-1.349E+01 BETAAC= 1.152E+01      GM= 6.328E-03      RPI= 2.113E+0
345      RO= 4.304E+05      CPI= 2.691E-12      CMU= 1.830E-13 BETAAC= 1.337E+0
346      FT= 3.505E+08
347
348  NAME:  Q48      MODEL:  RPO
349
350      IB=-1.421E-05      IC=-1.637E-04      VBE=-6.906E-01      VBC= 1.222E+0
351      VCE=-1.351E+01 BETAAC= 1.152E+01      GM= 6.335E-03      RPI= 2.111E+0
352      RO= 4.301E+05      CPI= 2.692E-12      CMU= 1.828E-13 BETAAC= 1.337E+0
353      FT= 3.507E+08
354
355  NAME:  Q49      MODEL:  RNO
356
357      IB= 3.183E-06      IC= 6.156E-05      VBE= 6.541E-01      VBC=-1.222E+0
358      VCE= 1.347E+01 BETAAC= 1.934E+01      GM= 2.328E-03      RPI= 9.887E+0
359      RO= 1.383E+06      CPI= 9.970E-13      CMU= 2.688E-13 BETAAC= 2.361E+0
360      FT= 3.003E+08
361
362  NAME:  Q50      MODEL:  RN1
363
364      IB= 9.015E-06      IC= 1.606E-04      VBE= 6.666E-01      VBC=-6.755E-0
365      VCE= 1.342E+00 BETAAC= 1.781E+01      GM= 6.222E-03      RPI= 3.449E+0
366      RO= 4.531E+05      CPI= 2.192E-12      CMU= 7.348E-13 BETAAC= 2.146E+0
367      FT= 3.384E+08
368
369  NAME:  Q51      MODEL:  RN1
370
371      IB= 9.016E-06      IC= 1.605E-04      VBE= 6.666E-01      VBC=-6.541E-0
372      VCE= 1.321E+00 BETAAC= 1.781E+01      GM= 6.221E-03      RPI= 3.449E+0
373      RO= 4.530E+05      CPI= 2.192E-12      CMU= 7.396E-13 BETAAC= 2.146E+0
374      FT= 3.377E+08
375
376  NAME:  Q52      MODEL:  RN1
377
378      IB= 1.902E-06      IC= 2.334E-05      VBE= 6.147E-01      VBC=-3.698E-0
379      VCE= 9.845E-01 BETAAC= 1.227E+01      GM= 9.067E-04      RPI= 1.724E+0
380      RO= 3.128E+06      CPI= 1.372E-12      CMU= 7.201E-13 BETAAC= 1.563E+0
381      FT= 6.899E+07
382
383  NAME:  Q53      MODEL:  RN1
384
385      IB= 1.902E-06      IC= 2.334E-05      VBE= 6.147E-01      VBC=-3.698E-0

```

386 VCE= 9.845E-01 BETADC= 1.227E+01 GM= 9.067E-04 RPI= 1.724E+0
 387 RO= 3.128E+06 CPI= 1.372E-12 CMU= 7.201E-13 BETAAC= 1.563E+0
 388 FT= 6.899E+07
 389
 390 NAME: Q54 MODEL: RP0
 391
 392 IB=-2.804E-05 IC=-3.557E-04 VBE=-7.150E-01 VBC= 1.247E+0
 393 VCE=-1.359E+01 BETADC= 1.268E+01 GM= 1.369E-02 RPI= 1.051E+0
 394 RO= 1.968E+05 CPI= 4.986E-12 CMU= 1.845E-13 BETAAC= 1.439E+0
 395 FT= 4.214E+08
 396
 397 NAME: Q55 MODEL: RP1
 398
 399 IB=-3.154E-05 IC=-3.051E-04 VBE=-6.974E-01 VBC= 6.691E-0
 400 VCE=-1.366E+00 BETADC= 9.675E+00 GM= 1.179E-02 RPI= 9.486E+0
 401 RO= 1.905E+05 CPI= 5.744E-12 CMU= 7.404E-13 BETAAC= 1.119E+0
 402 FT= 2.895E+08
 403
 404 NAME: Q56 MODEL: RP1
 405
 406 IB=-1.427E-05 IC=-1.467E-04 VBE=-6.691E-01 VBC= 1.307E+0
 407 VCE=-1.374E+01 BETADC= 1.028E+01 GM= 5.692E-03 RPI= 2.140E+0
 408 RO= 4.828E+05 CPI= 3.109E-12 CMU= 2.596E-13 BETAAC= 1.218E+0
 409 FT= 2.690E+08
 410
 411 NAME: Q57 MODEL: RNO
 412
 413 IB= 1.199E-05 IC= 3.194E-04 VBE= 6.983E-01 VBC=-1.977E+0
 414 VCE= 2.047E+01 BETADC= 2.663E+01 GM= 1.231E-02 RPI= 2.509E+0
 415 RO= 2.844E+05 CPI= 2.171E-12 CMU= 2.486E-13 BETAAC= 3.087E+0
 416 FT= 8.093E+08
 417
 418 NAME: Q58 MODEL: RNO
 419
 420 IB= 2.974E-06 IC= 5.665E-05 VBE= 6.519E-01 VBC=-1.240E+0
 421 VCE= 1.345E+01 BETADC= 1.905E+01 GM= 2.198E-03 RPI= 1.060E+0
 422 RO= 1.502E+06 CPI= 9.723E-13 CMU= 2.688E-13 BETAAC= 2.331E+0
 423 FT= 2.819E+08
 424
 425 NAME: Q59 MODEL: RN1
 426
 427 IB= 3.224E-06 IC= 4.543E-05 VBE= 6.322E-01 VBC=-3.934E-0
 428 VCE= 1.026E+00 BETADC= 1.409E+01 GM= 1.764E-03 RPI= 9.991E+0
 429 RO= 1.605E+06 CPI= 1.512E-12 CMU= 7.275E-13 BETAAC= 1.742E+0
 430 FT= 1.254E+08
 431
 432 NAME: Q60 MODEL: RN1
 433
 434 IB= 1.646E-05 IC= 3.267E-04 VBE= 6.875E-01 VBC=-6.445E-0
 435 VCE= 1.332E+00 BETADC= 1.985E+01 GM= 1.262E-02 RPI= 1.851E+0
 436 RO= 2.209E+05 CPI= 3.165E-12 CMU= 9.405E-13 BETAAC= 2.337E+0
 437 FT= 4.894E+08
 438
 439 NAME: Q61 MODEL: RP0
 440

441	IR=-2.306E-05	IC=-2.861E-04	VBE=-7.077E-01	VBC= 1.308E+0
442	VCE=-1.378E+01	BETAOC= 1.240E+01	GM= 1.103E-02	RPI= 1.245E+0
443	RO= 2.460E+05	CPI= 4.139E-12	CMU= 1.829E-13	BETAAC= 1.417E+0
444	FT= 4.043E+08			
445				
446	NAME: Q62	MODEL: RN1LC		
447				
448	IR= 1.245E-05	IC= 2.341E-04	VBE= 6.777E-01	VBC= 0.000E+0
449	VCE= 6.777E-01	BETAOC= 1.881E+01	GM= 9.061E-03	RPI= 2.472E+0
450	RO= 3.004E+05	CPI= 2.629E-12	CMU= 1.047E-12	BETAAC= 2.240E+0
451	FT= 3.923E+08			
452				
453	NAME: Q63	MODEL: RP1LC		
454				
455	IR=-2.414E-05	IC=-2.223E-04	VBE=-6.875E-01	VBC= 0.000E+0
456	VCE=-6.875E-01	BETAOC= 9.208E+00	GM= 8.605E-03	RPI= 1.248E+0
457	RO= 2.600E+05	CPI= 4.582E-12	CMU= 1.053E-12	BETAAC= 1.074E+0
458	FT= 2.430E+08			
459				
460	NAME: Q64	MODEL: RN1		
461				
462	IR= 4.662E-06	IC= 8.438E-05	VBE= 6.445E-01	VBC=-1.320E+0
463	VCE= 1.384E+01	BETAOC= 1.810E+01	GM= 3.276E-03	RPI= 6.823E+0
464	RO= 1.014E+06	CPI= 1.672E-12	CMU= 3.956E-13	BETAAC= 2.235E+0
465	FT= 2.522E+08			
466				
467	NAME: Q65	MODEL: RN1		
468				
469	IR= 1.417E-05	IC= 3.197E-04	VBE= 6.822E-01	VBC=-1.275E+0
470	VCE= 1.343E+01	BETAOC= 2.256E+01	GM= 1.237E-02	RPI= 2.161E+0
471	RO= 2.637E+05	CPI= 2.857E-12	CMU= 4.028E-13	BETAAC= 2.672E+0
472	FT= 6.037E+08			
473				
474	NAME: Q66	MODEL: RN1LC		
475				
476	IR= 1.655E-05	IC= 3.173E-04	VBE= 6.870E-01	VBC= 0.000E+0
477	VCE= 6.870E-01	BETAOC= 1.917E+01	GM= 1.227E-02	RPI= 1.889E+0
478	RO= 5.297E+04	CPI= 3.121E-12	CMU= 2.252E-12	BETAAC= 2.319E+0
479	FT= 3.636E+08			
480				
481	NAME: Q67	MODEL: RN8C		
482				
483	IR= 3.956E-05	IC= 7.352E-04	VBE= 6.486E-01	VBC=-1.430E+0
484	VCE= 1.495E+01	BETAOC= 1.858E+01	GM= 2.854E-02	RPI= 8.025E+0
485	RO= 1.179E+05	CPI= 1.307E-11	CMU= 1.848E-12	BETAAC= 2.290E+0
486	FT= 3.044E+08			
487				
488	NAME: Q68	MODEL: RP8C		
489				
490	IR=-7.312E-05	IC=-7.027E-04	VBE=-6.545E-01	VBC= 1.427E+0
491	VCE=-1.492E+01	BETAOC= 9.611E+00	GM= 2.728E-02	RPI= 4.226E+0
492	RO= 1.027E+05	CPI= 1.873E-11	CMU= 1.171E-12	BETAAC= 1.153E+0
493	FT= 2.182E+08			
494				
495	NAME: Q69	MODEL: RN1LC		

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496
497      IR= 9.063E-06      IC= 1.605E-04      VBE= 6.668E-01      VBC= 0.000E+0
498      VCE= 6.668E-01      BETADC= 1.771E+01      GM= 6.220E-03      RPI= 3.430E+0
499      RO= 4.500E+05      CPI= 2.198E-12      CMU= 9.432E-13      BETAAC= 2.134E+0
500      FT= 3.151E+08
501
502      NAME:  Q70      MODEL:  RN1LC
503
504      IR= 9.063E-06      IC= 1.605E-04      VBE= 6.668E-01      VBC= 0.000E+0
505      VCE= 6.668E-01      BETADC= 1.771E+01      GM= 6.219E-03      RPI= 3.431E+0
506      RO= 4.500E+05      CPI= 2.198E-12      CMU= 9.432E-13      BETAAC= 2.133E+0
507      FT= 3.151E+08
508
509      NAME:  Q71      MODEL:  RN1LC
510
511      IR= 4.127E-06      IC= 6.148E-05      VBE= 6.404E-01      VBC= 0.000E+0
512      VCE= 6.404E-01      BETADC= 1.490E+01      GM= 2.386E-03      RPI= 7.740E+0
513      RO= 1.179E+06      CPI= 1.611E-12      CMU= 8.403E-13      BETAAC= 1.847E+0
514      FT= 1.549E+08
515
516      NAME:  Q72      MODEL:  RP1LC
517
518      IR=-9.010E-06      IC=-6.947E-05      VBE=-6.537E-01      VBC= 0.000E+0
519      VCE=-6.537E-01      BETADC= 7.699E+00      GM= 2.692E-03      RPI= 3.431E+0
520      RO= 8.360E+05      CPI= 2.379E-12      CMU= 9.047E-13      BETAAC= 9.236E+0
521      FT= 1.305E+08
522
523      NAME:  Q73      MODEL:  RN0
524
525      IR=-7.342E-11      IC= 7.369E-11      VBE= 0.000E+00      VBC=-1.210E+0
526      VCE= 1.210E+01      BETADC=-1.004E+00      GM=-1.491E-14      RPI= 8.237E+1
527      RO= 3.885E+13      CPI= 4.500E-13      CMU= 2.708E-13      BETAAC=-1.228E-0
528      FT=-3.292E-03
529
530      NAME:  Q74      MODEL:  RN1
531
532      IR=-1.815E-10      IC= 1.822E-10      VBE=-1.944E-03      VBC=-1.496E+0
533      VCE= 1.496E+01      BETADC=-1.004E+00      GM=-3.687E-14      RPI= 4.119E+1
534      RO= 1.837E+13      CPI= 8.193E-13      CMU= 3.843E-13      BETAAC=-1.518E-0
535      FT=-4.875E-03
536
537      NAME:  Q75      MODEL:  RP1
538
539      IR= 1.268E-10      IC=-1.273E-10      VBE=-1.944E-03      VBC= 1.493E+0
540      VCE=-1.493E+01      BETADC=-1.004E+00      GM=-2.445E-14      RPI= 5.725E+1
541      RO= 2.451E+13      CPI= 9.507E-13      CMU= 2.473E-13      BETAAC=-1.400E-0
542      FT=-3.248E-03
543
544      NAME:  Q76      MODEL:  RP0
545
546      IR= 5.108E-12      IC=-5.124E-12      VBE= 0.000E+00      VBC= 1.202E+0
547      VCE=-1.202E+00      BETADC=-1.003E+00      GM=-1.092E-15      RPI= 1.210E+1
548      RO= 7.058E+13      CPI= 5.200E-13      CMU= 3.670E-13      BETAAC=-1.321E-0
549      FT=-1.959E-04
550

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551 NAME: Q77 MODEL: RP1
552
553 IB= 1.022E-11 IC=-1.025E-11 VBF= 0.000E+00 VBC= 1.202E+0
554 VCE=-1.202E+00 BETADC=-1.003E+00 GM=-2.184E-15 RPI= 6.048E+1
555 RO= 3.529E+13 CPI= 9.500E-13 CMU= 5.260E-13 BETAAC=-1.321E-0
556 FT=-2.355E-04
557
558 NAME: Q78 MODEL: RP0
559
560 IB= 5.108E-12 IC=-5.124E-12 VBF= 0.000E+00 VBC= 1.202E+0
561 VCE=-1.202E+00 BETADC=-1.003E+00 GM=-1.092E-15 RPI= 1.210E+1
562 RO= 7.058E+13 CPI= 5.200E-13 CMU= 3.670E-13 BETAAC=-1.321E-0
563 FT=-1.959E-04
564
565 NAME: Q79 MODEL: RN1
566
567 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
568 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
569 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
570 FT=-2.993E-04
571
572 NAME: Q80 MODEL: RN1
573
574 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
575 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
576 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
577 FT=-2.993E-04
578
579 NAME: Q81 MODEL: RN1
580
581 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
582 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
583 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
584 FT=-2.993E-04
585
586 NAME: Q82 MODEL: RN1
587
588 IB=-1.334E-11 IC= 1.339E-11 VBE= 0.000E+00 VBC=-1.099E+0
589 VCE= 1.099E+00 BETADC=-1.003E+00 GM=-2.710E-15 RPI= 4.119E+1
590 RO= 2.496E+13 CPI= 8.200E-13 CMU= 6.211E-13 BETAAC=-1.116E-0
591 FT=-2.993E-04
592
593 NAME: Q83 MODEL: RP0
594
595 IB= 6.717E-11 IC=-6.744E-11 VBE= 0.000E+00 VBC= 1.581E+0
596 VCE=-1.581E+01 BETADC=-1.004E+00 GM=-1.436E-14 RPI= 1.210E+1
597 RO= 4.807E+13 CPI= 5.200E-13 CMU= 1.694E-13 BETAAC=-1.737E-0
598 FT=-3.315E-03
599
600 NAME: Q84 MODEL: RN8C
601
602 IB=-1.326E-10 IC= 1.330E-10 VBE= 0.000E+00 VBC=-1.345E+0
603 VCE= 1.365E+00 BETADC=-1.003E+00 GM=-2.692E-14 RPI= 5.148E+1
604 RO= 3.099E+12 CPI= 6.200E-12 CMU= 2.855E-12 BETAAC=-1.386E-0
605 FT=-4.732E-04

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506
 507 NAME: QAS MODEL: RNO
 508
 509 IB=-1.301E-11 IC= 1.306E-11 VBF= 0.000F+00 VBC=-2.145E+00
 510 VCE= 2.145E+00 BETANC=-1.003E+00 GM=-2.643E-15 RPI= 8.237E+11
 511 RO= 4.860E+13 CPI= 4.500E-13 CMII= 3.766E-13 BETAAC=-2.177E-03
 512 FT=-5.089E-04

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APPENDIX 3.0

AC and TRANSIENT SIMULATIONS

- 3.1 25° AC and Step Response
- 3.2 125° " " "
- 3.3 -55° " " "
- 3.4 25° Post-Neutron AC and Step Responses

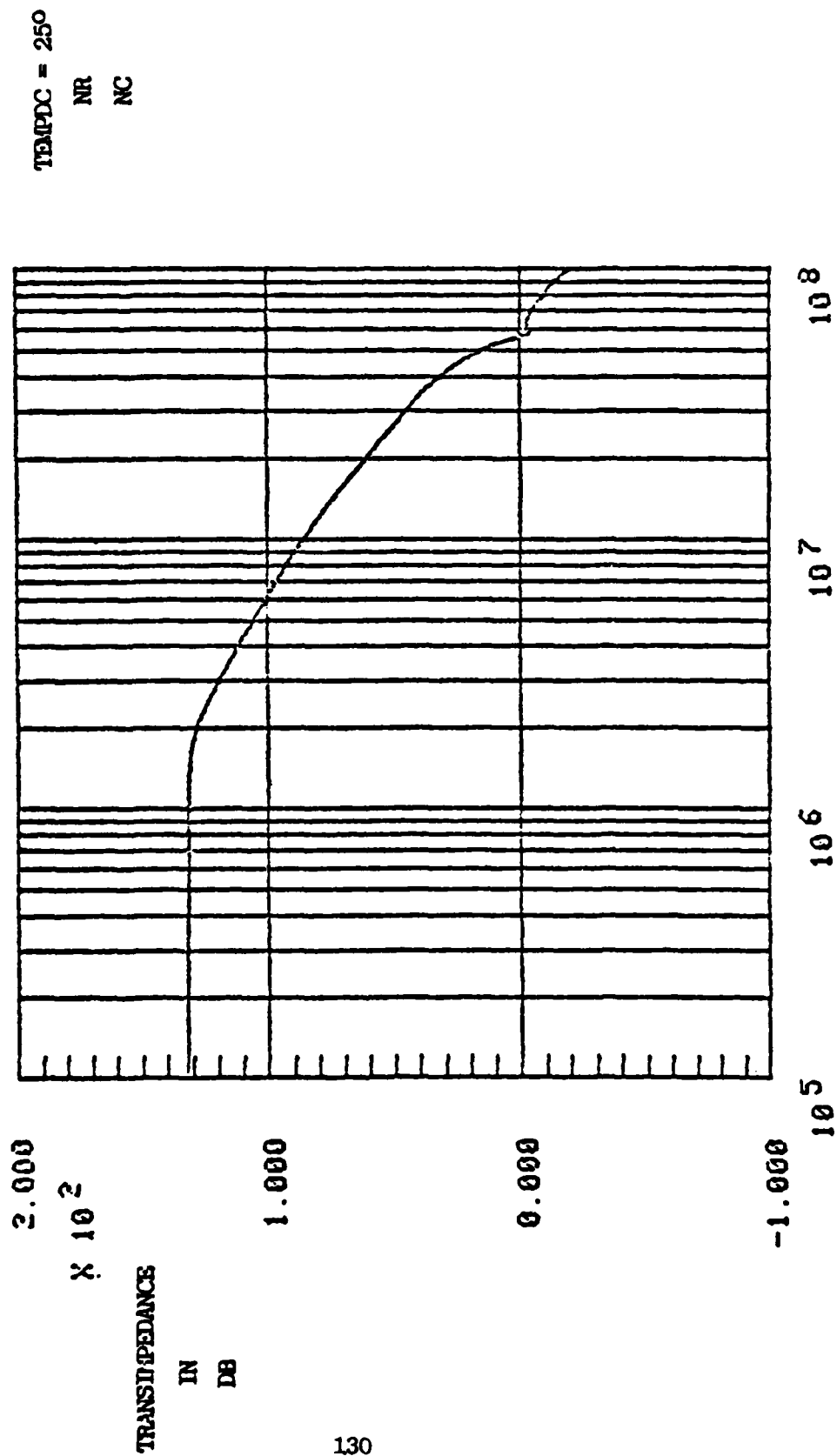
Key: Abbreviations for Process Variation

NR, NC: Nominal Resistors
Nominal Capacitors

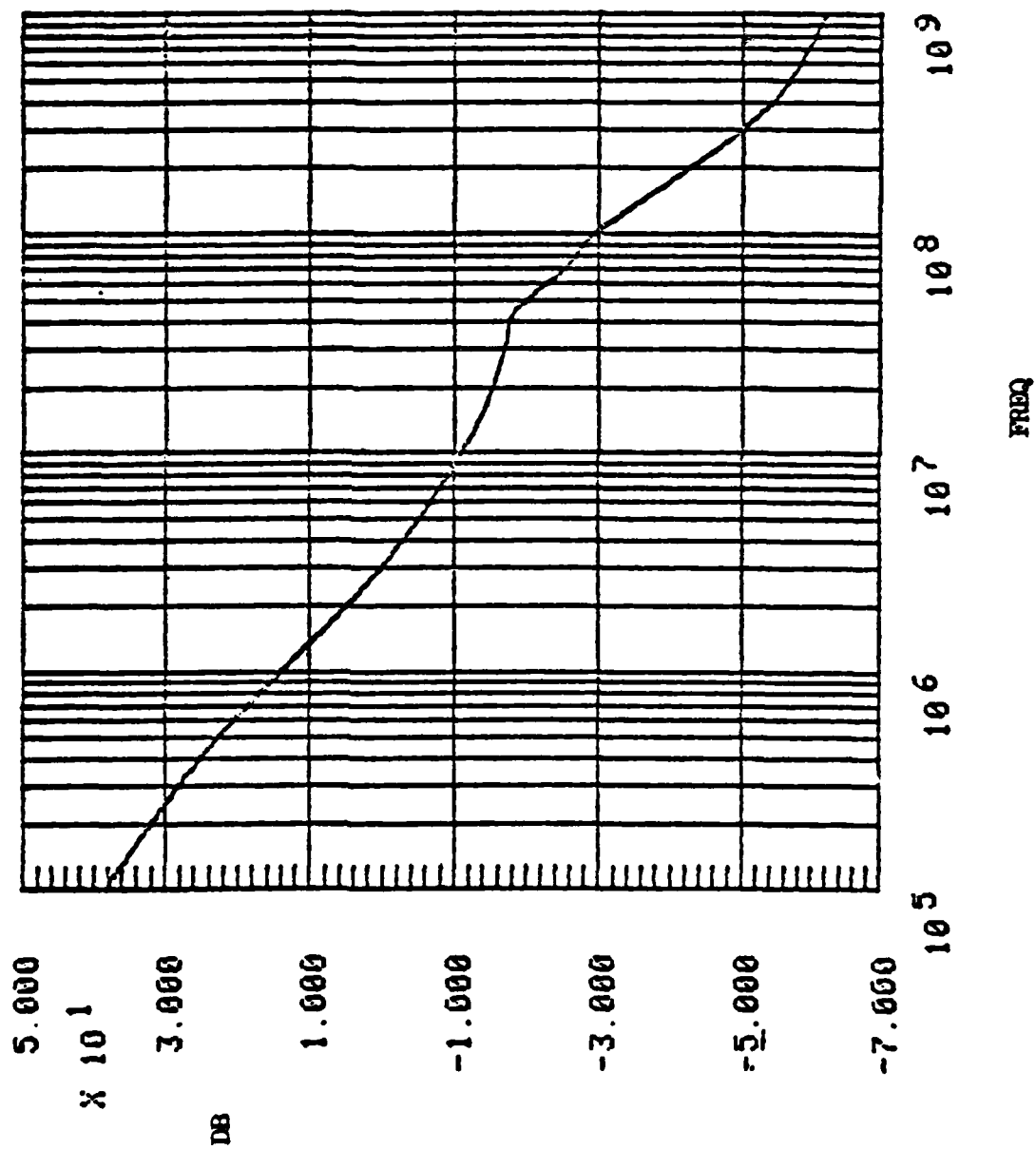
HR, HC: 10% High Resistors
10% High Capacitors

LR, LC: 10% Low Resistors
10% Low Capacitors

OVERALL GAIN



A₁ OPEN-LOOP GAIN



A₁ OPEN-LOOP PHASE

2.000

$\times 10^2$

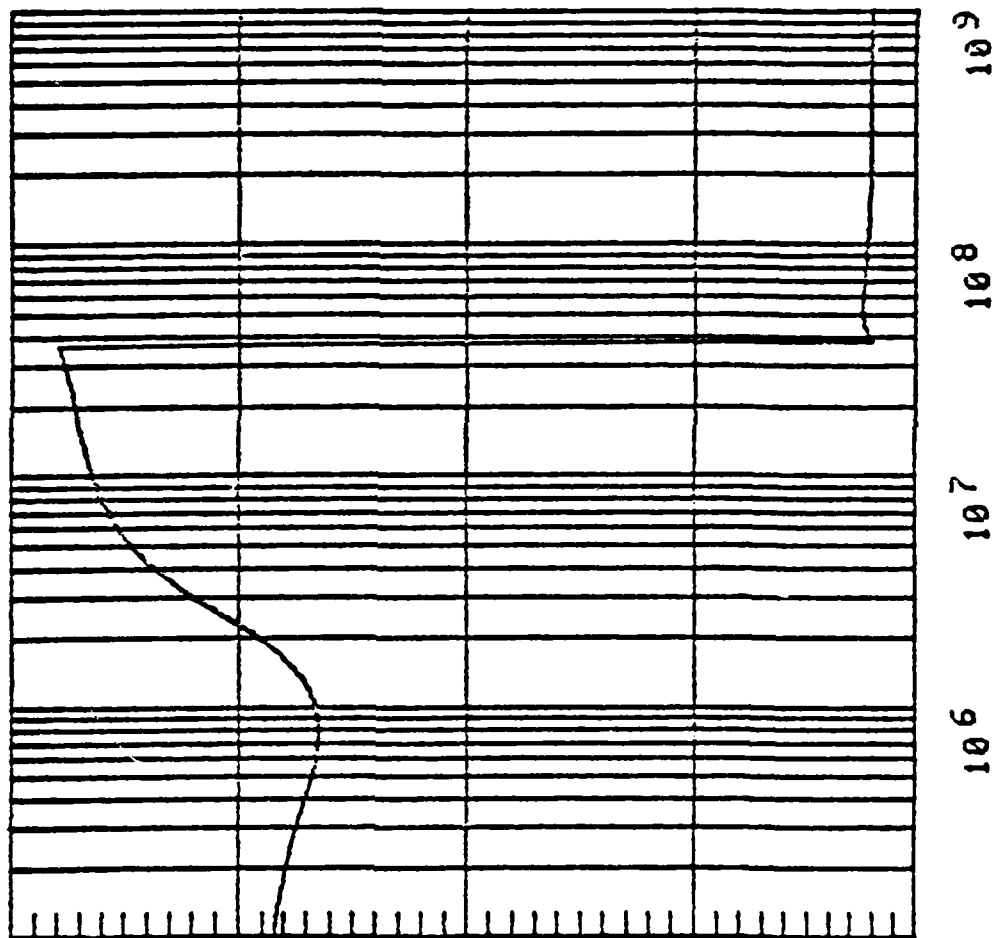
DEGREES

1.000

0.000

-1.000

-2.000



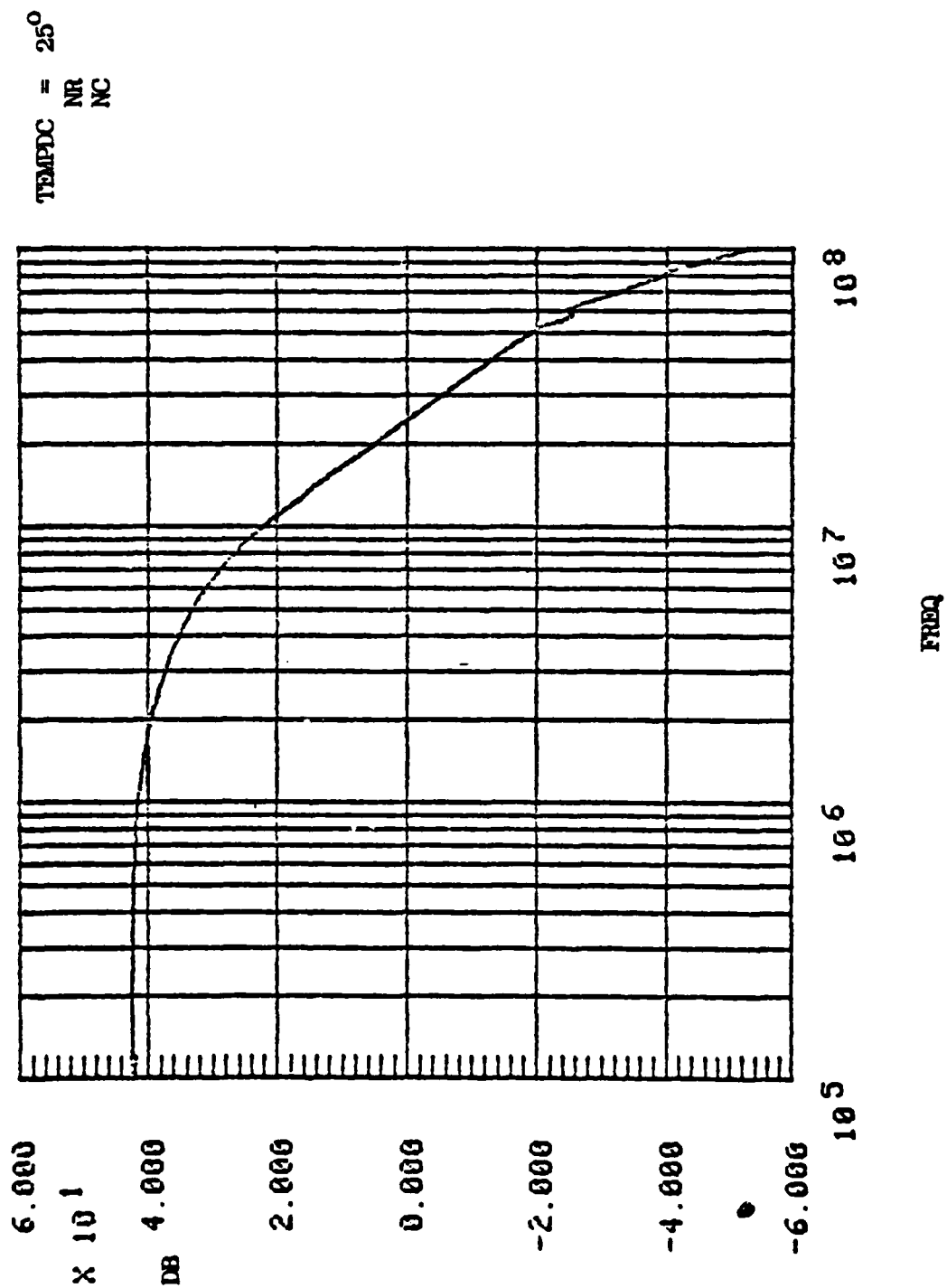
TEMP DC = 25°

NR
NC

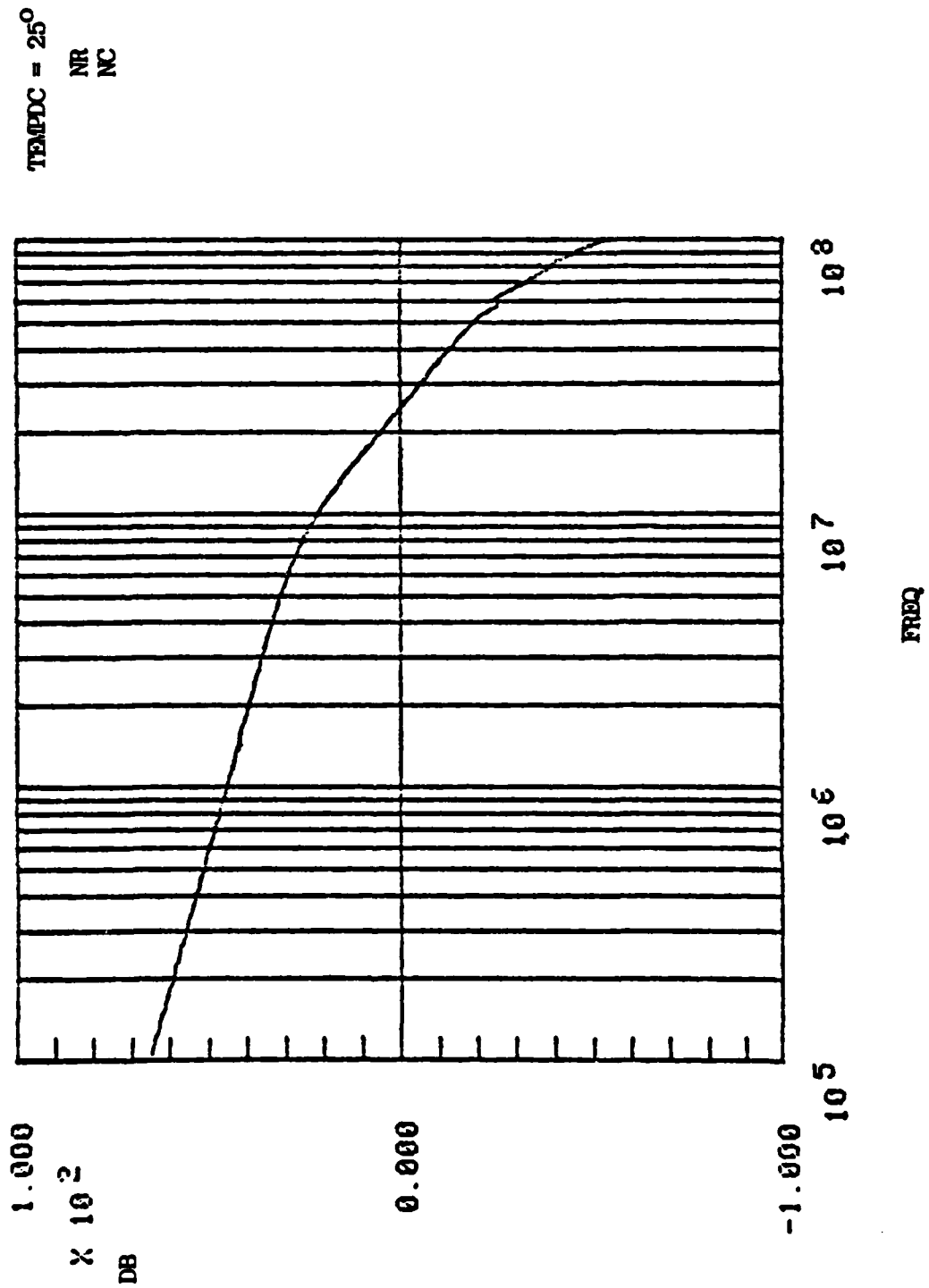
Note: Low frequency phase is 180° since configuration is inverting

$\phi_m = 65^\circ$

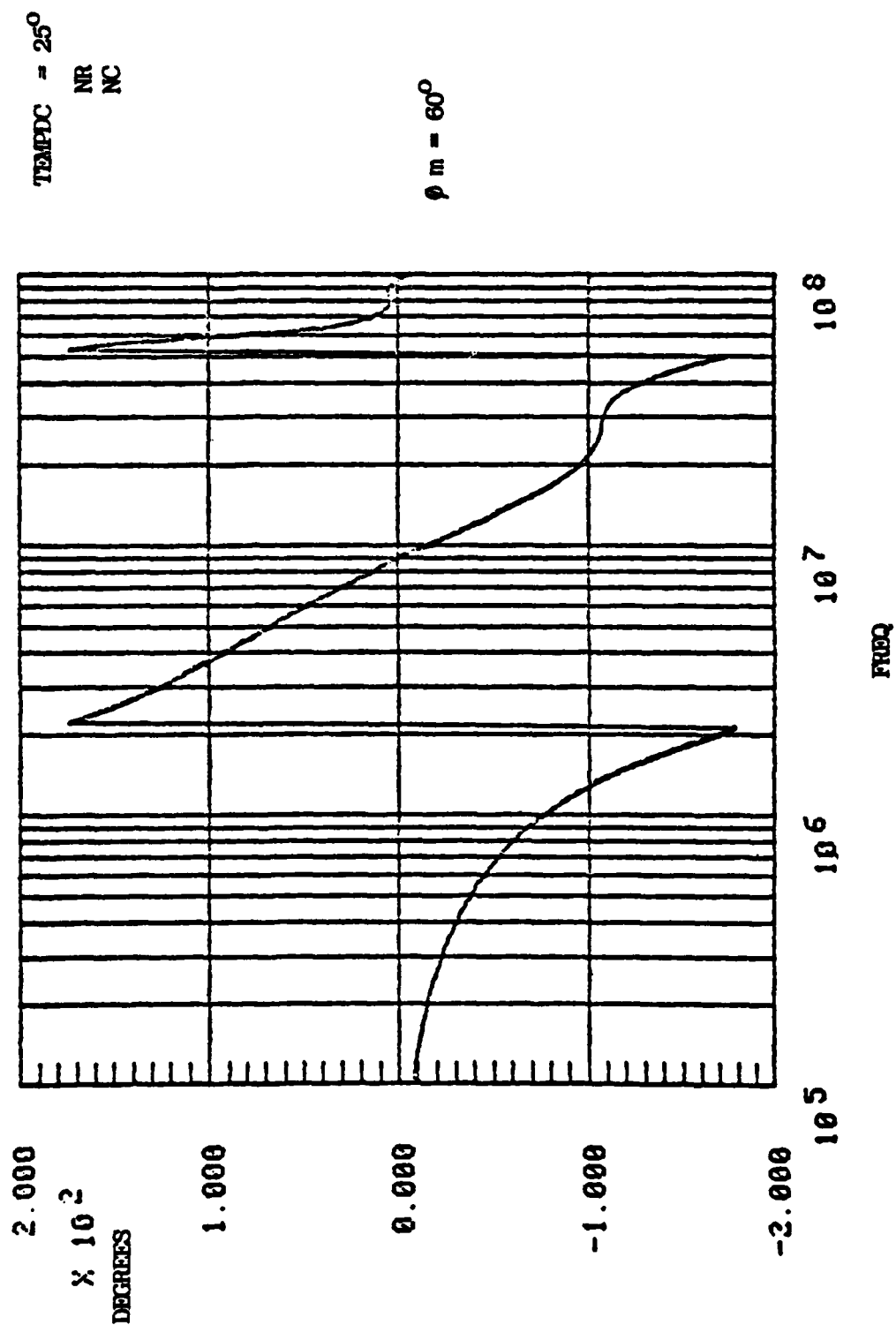
A₂ CLOSED-LOOP GAIN



A₂ OPEN-LOOP GAIN

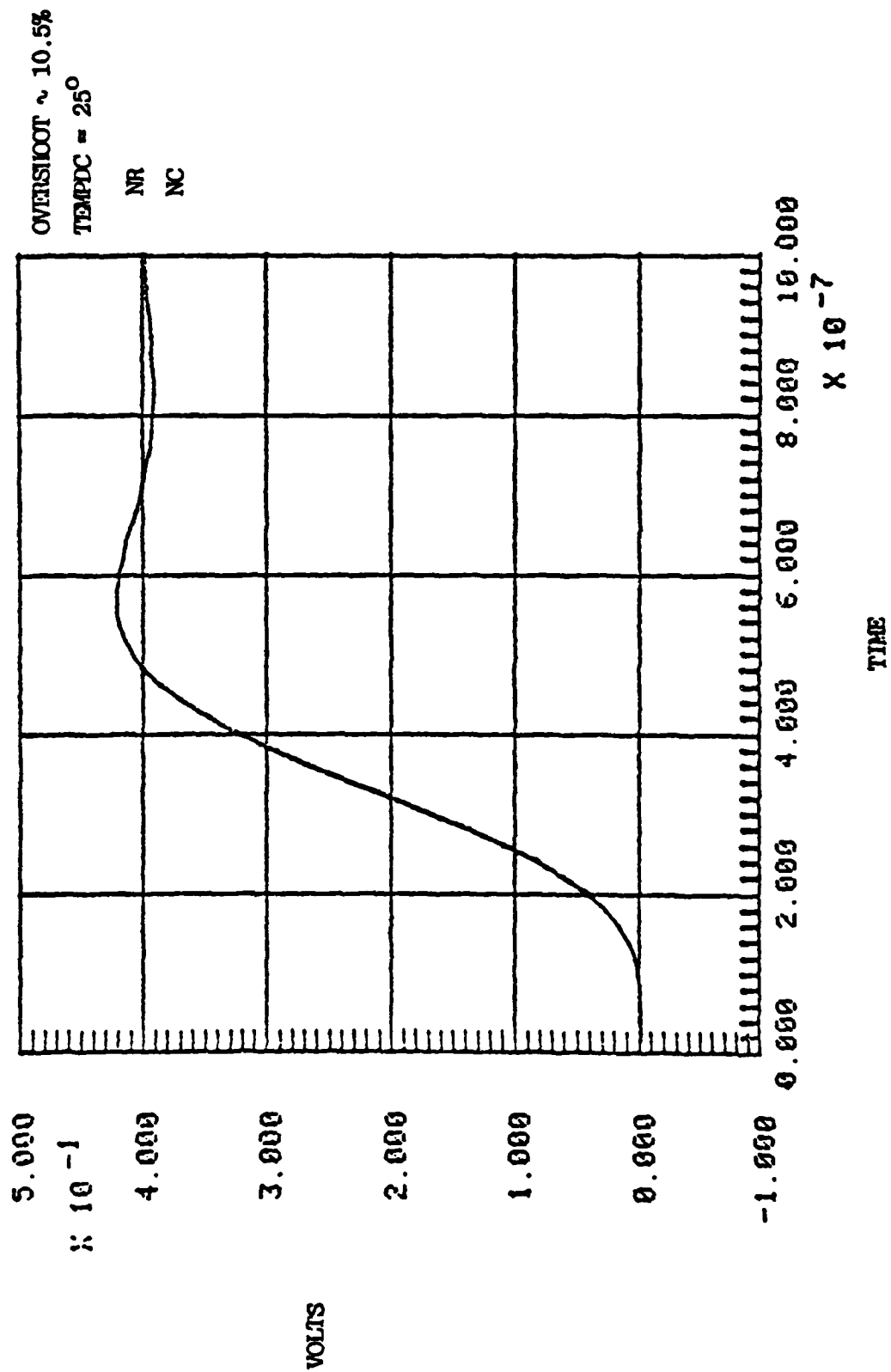


A₂ OPEN-LOOP PHASE



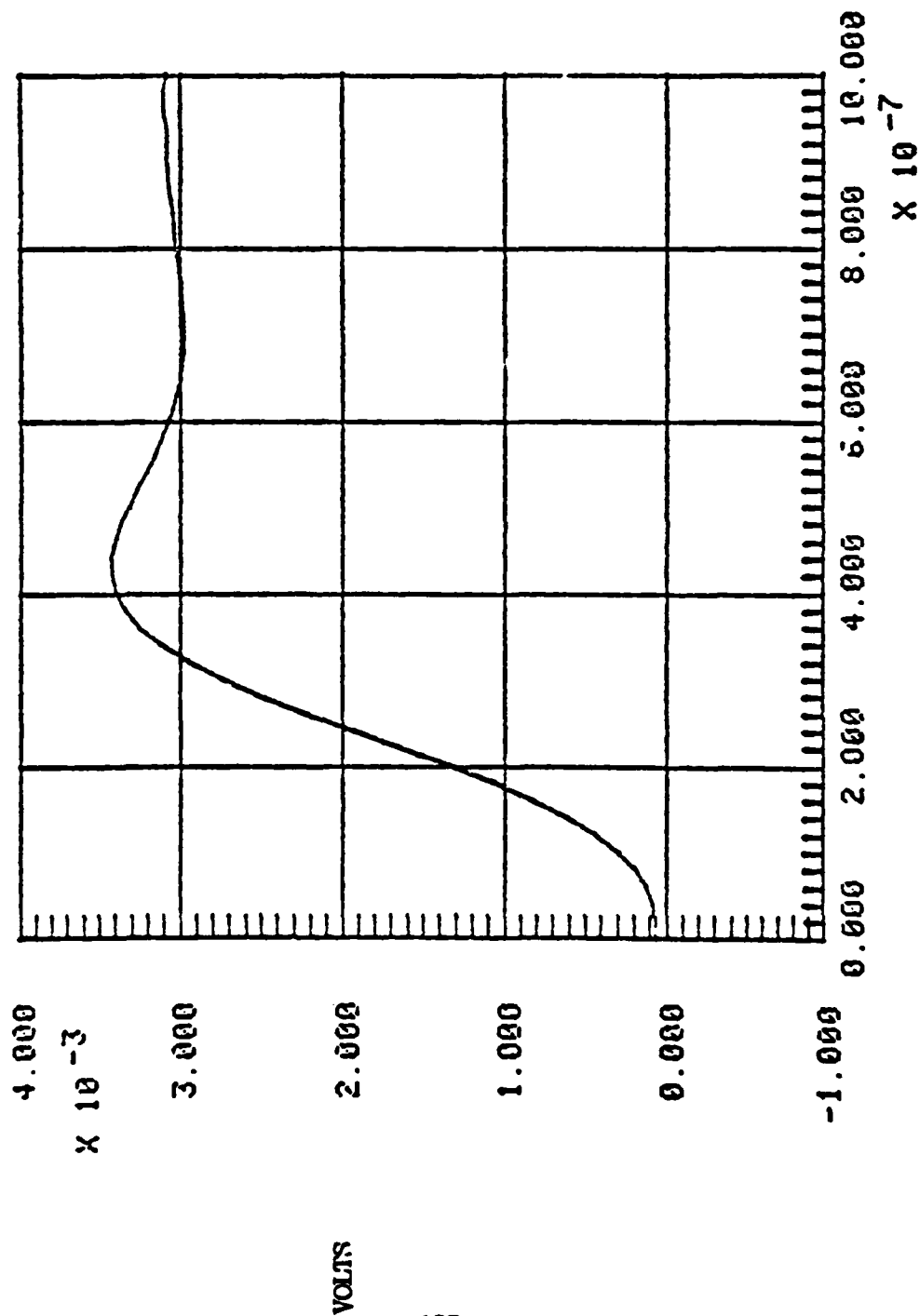
OVERALL STEP RESPONSE

100 nA STEP



A₁ STEP RESPONSE

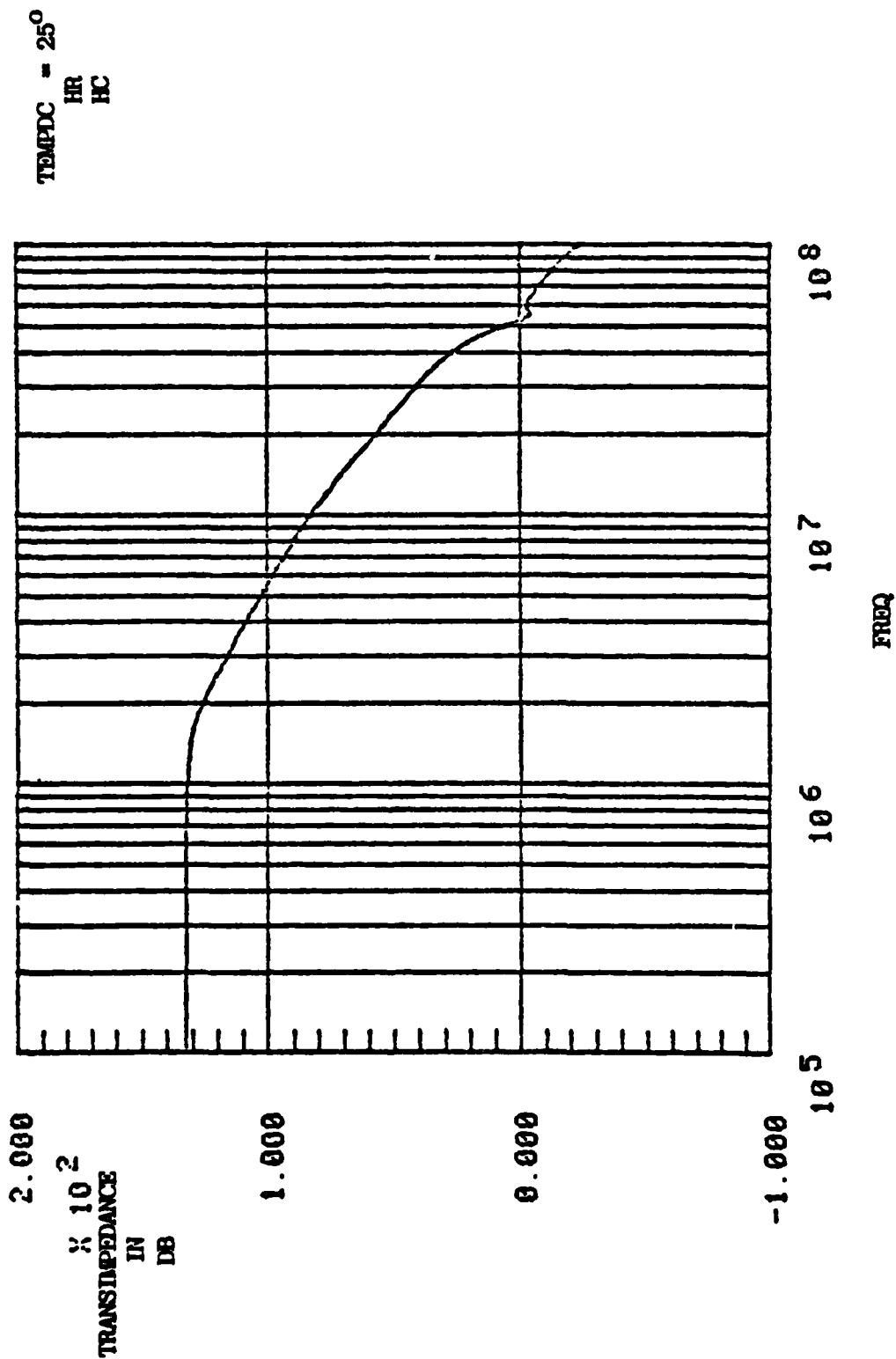
100 NA STEP

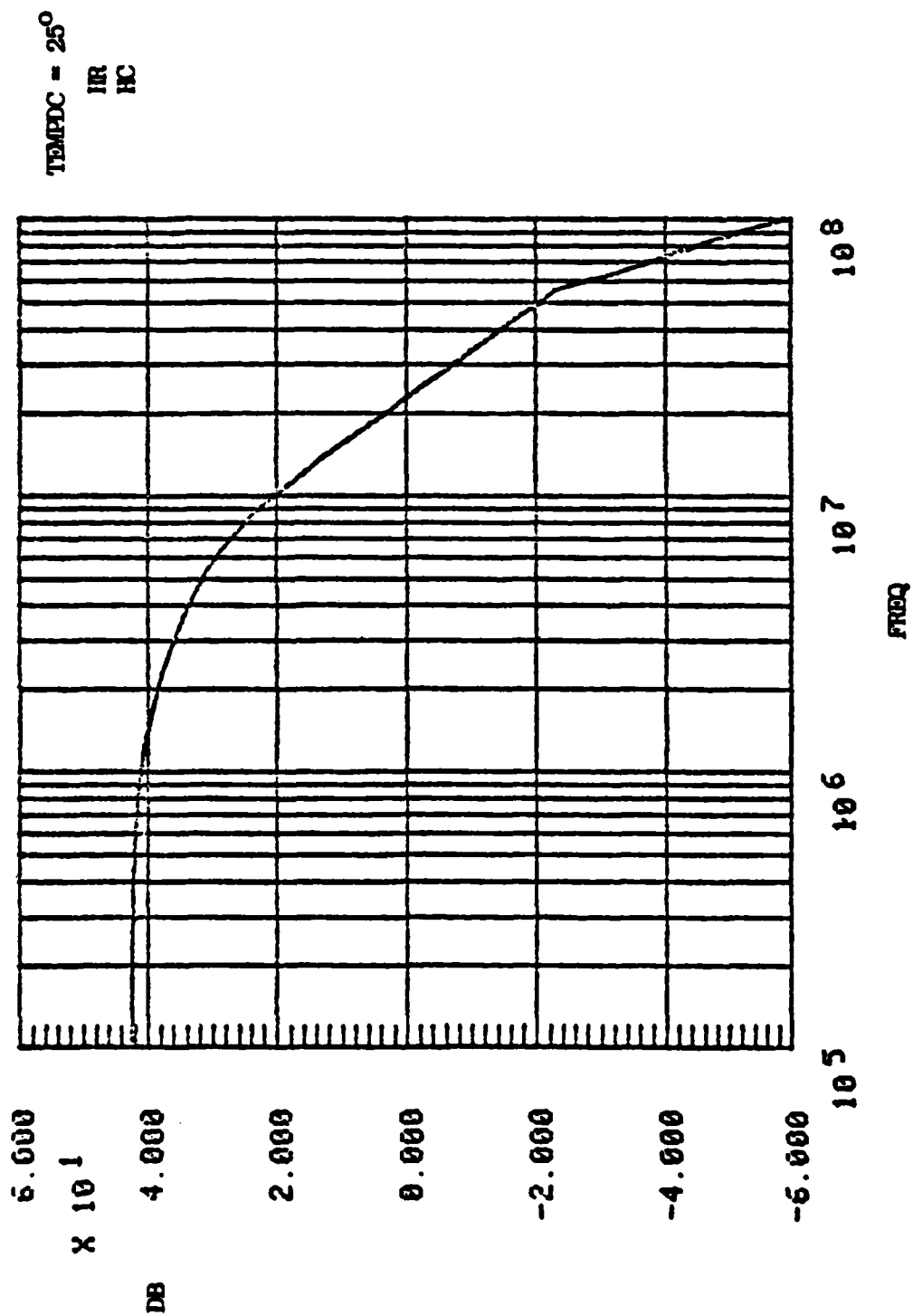


OVERSHOOT ~ 11.3%
TEMPDC = 25°C

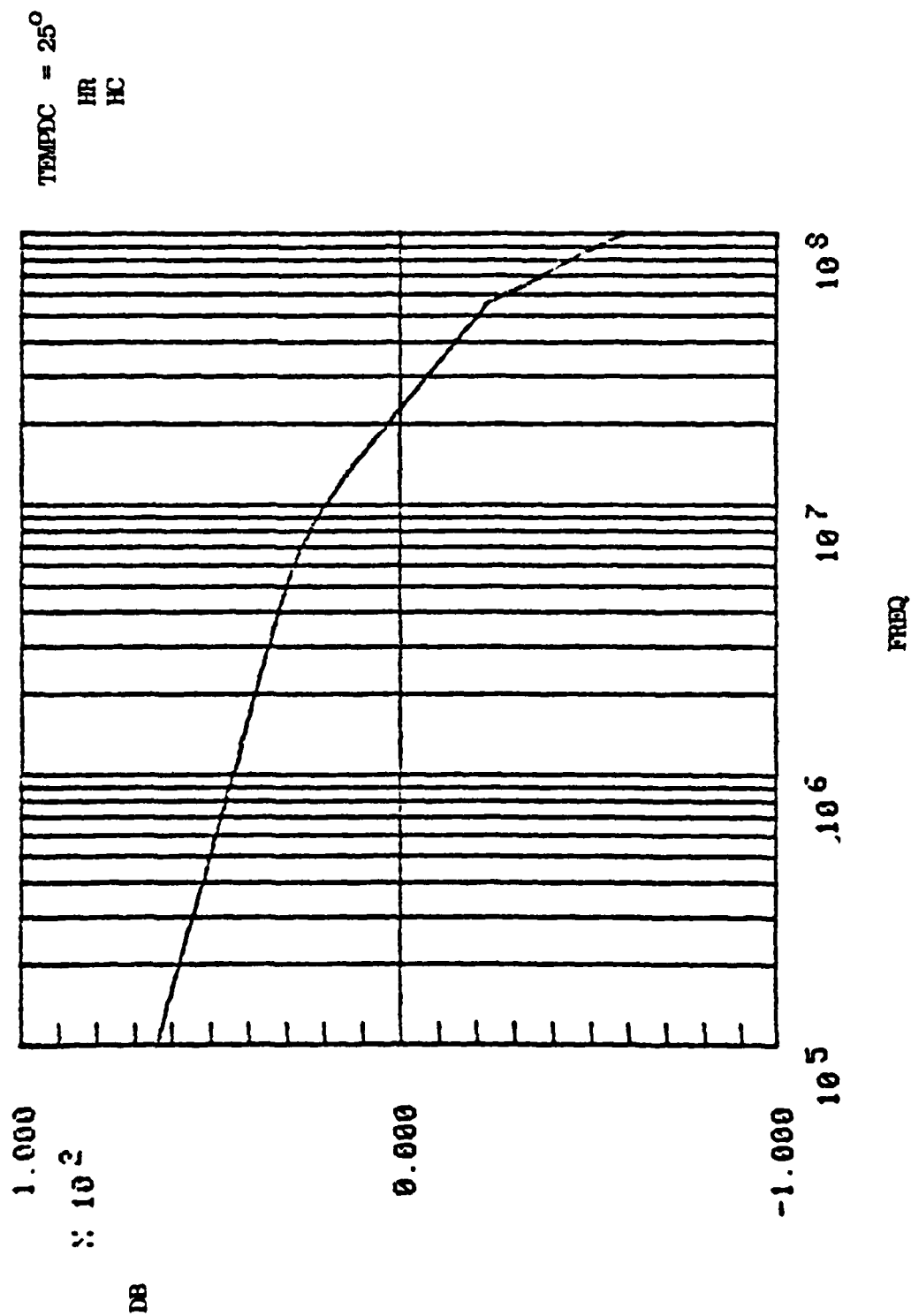
NR
NC

OVERALL GAIN

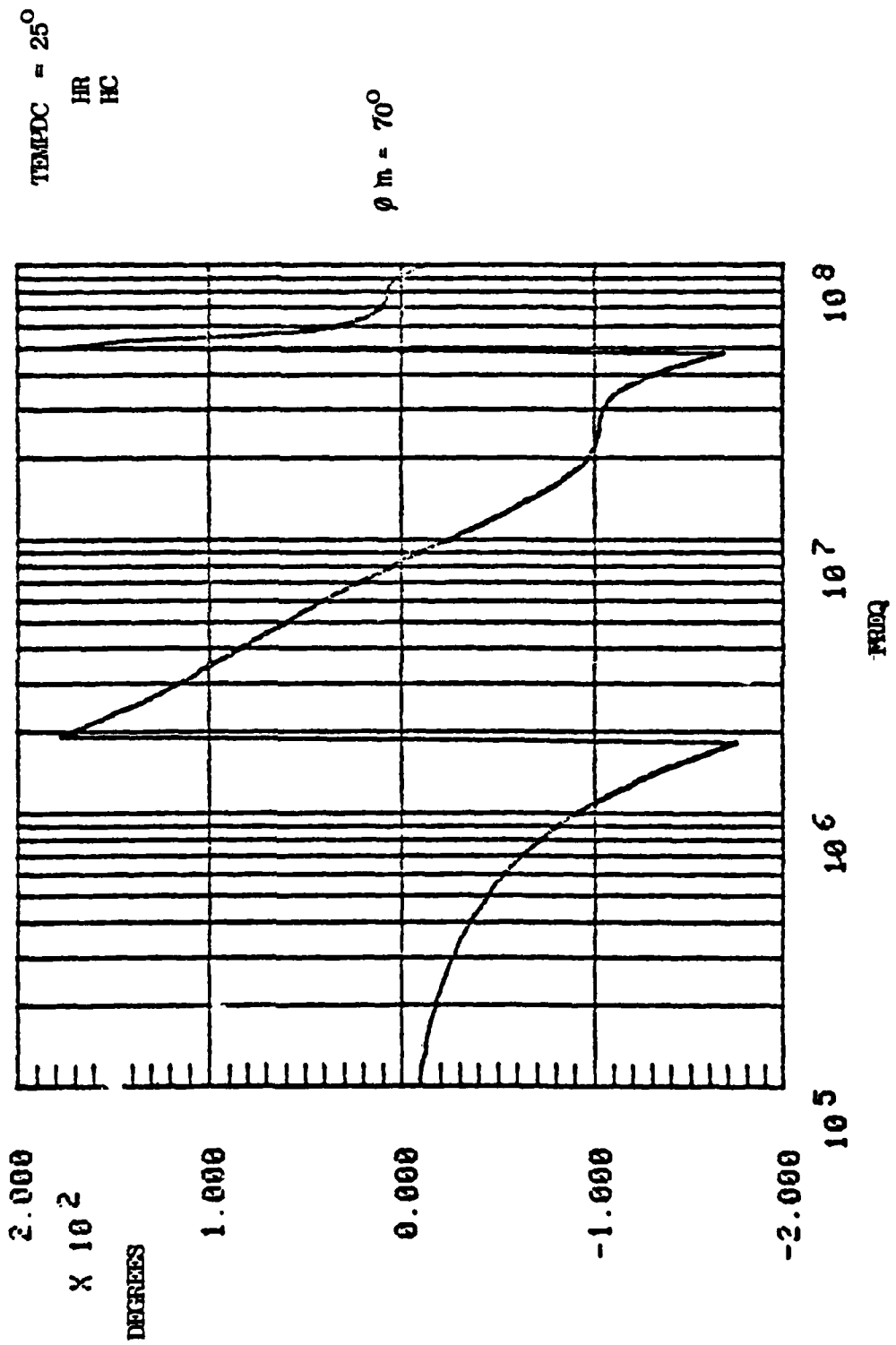


A₂ OPEN-LOOP GAIN

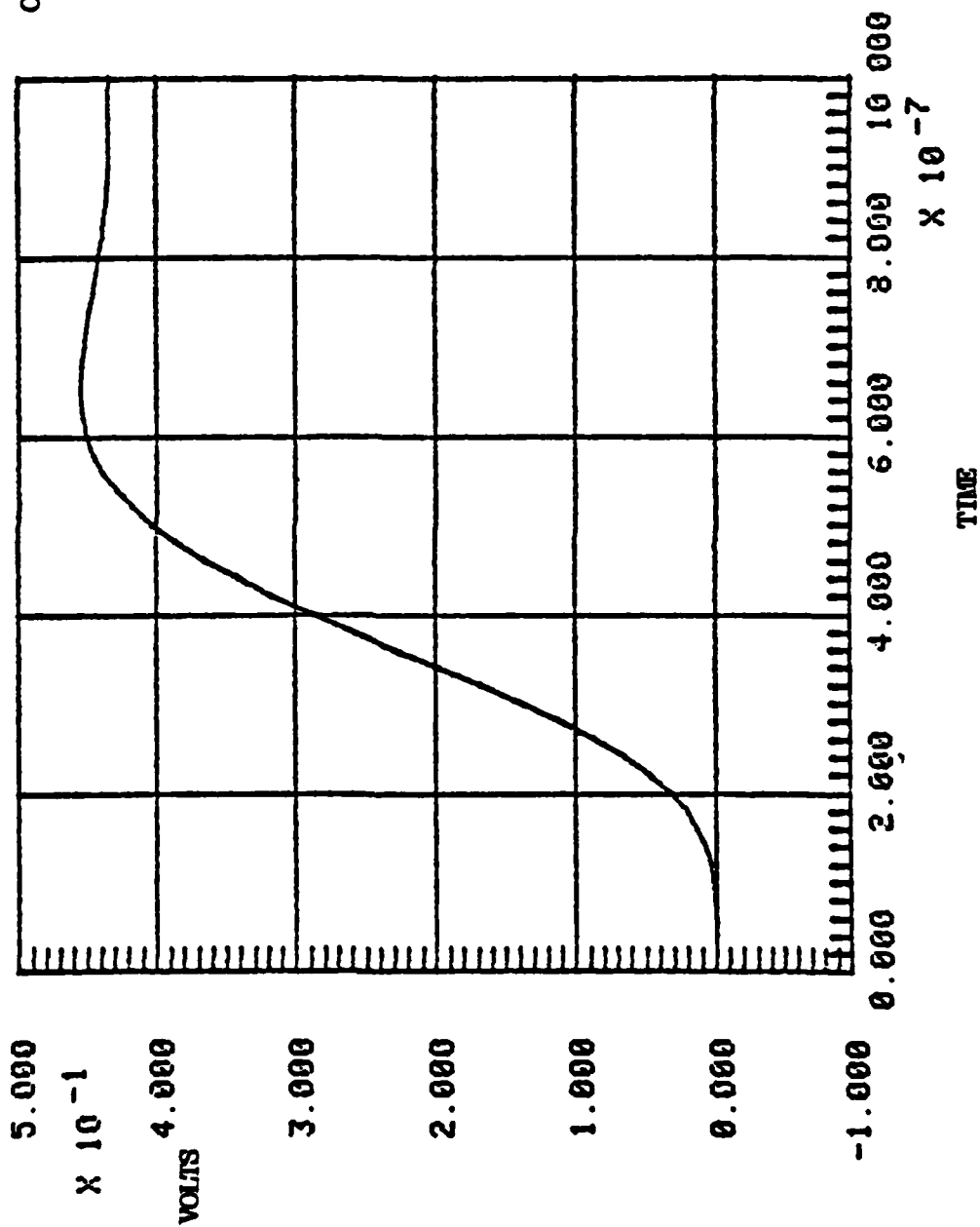
A_2 OPEN-LOOP GAIN



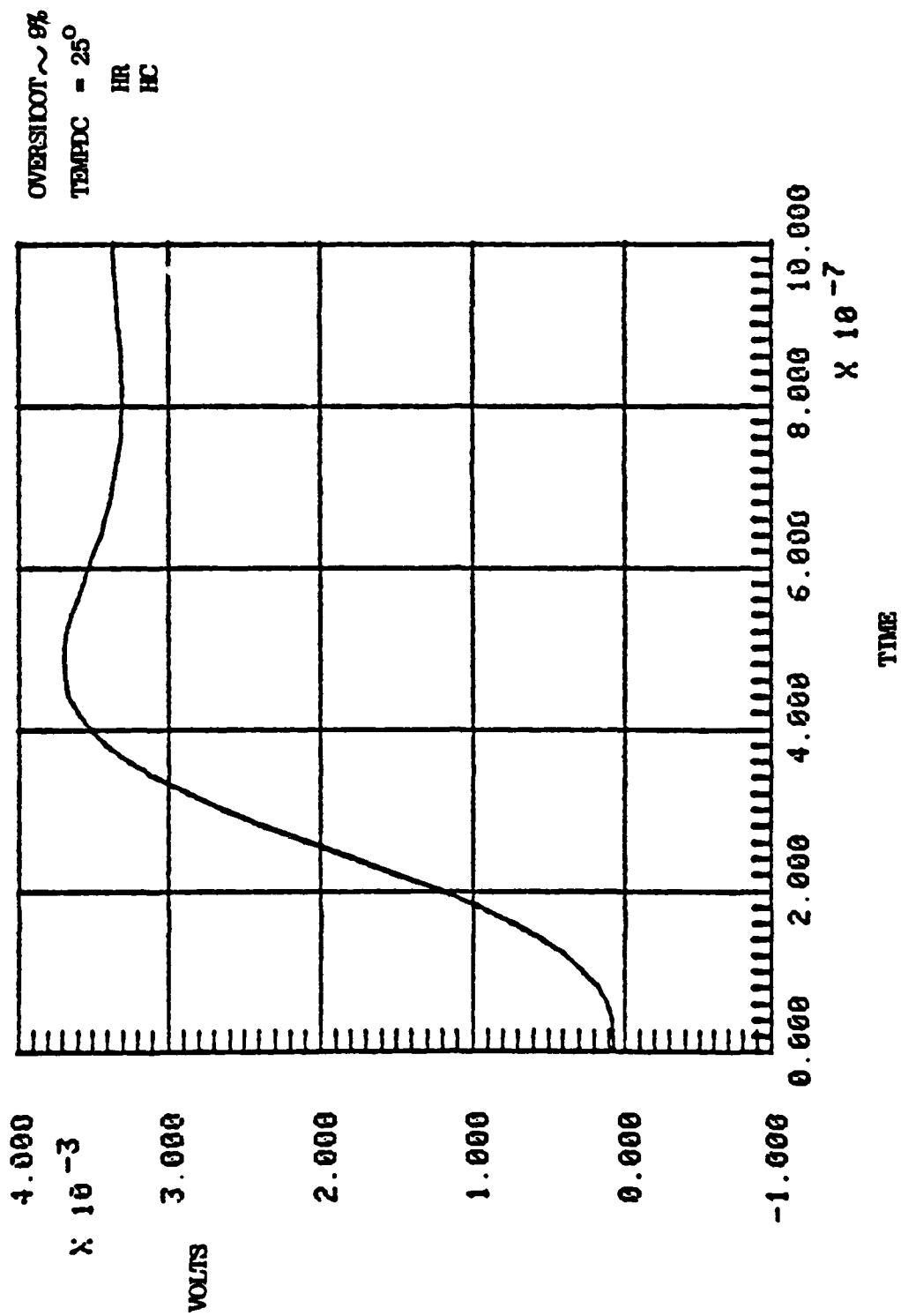
A₂ OPEN-LOOP PHASE



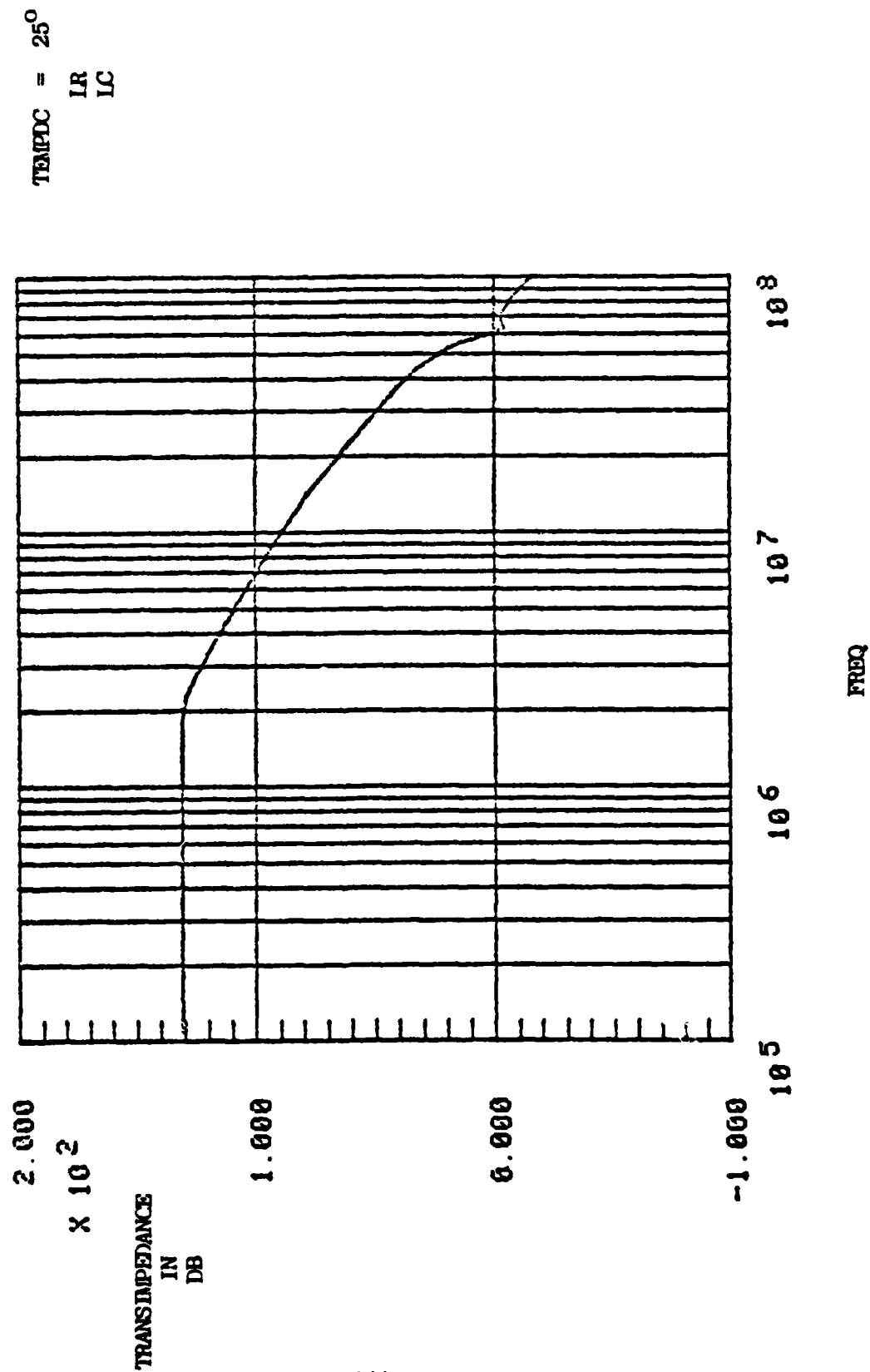
OVERALL STEP RESPONSE
100 nA STEP



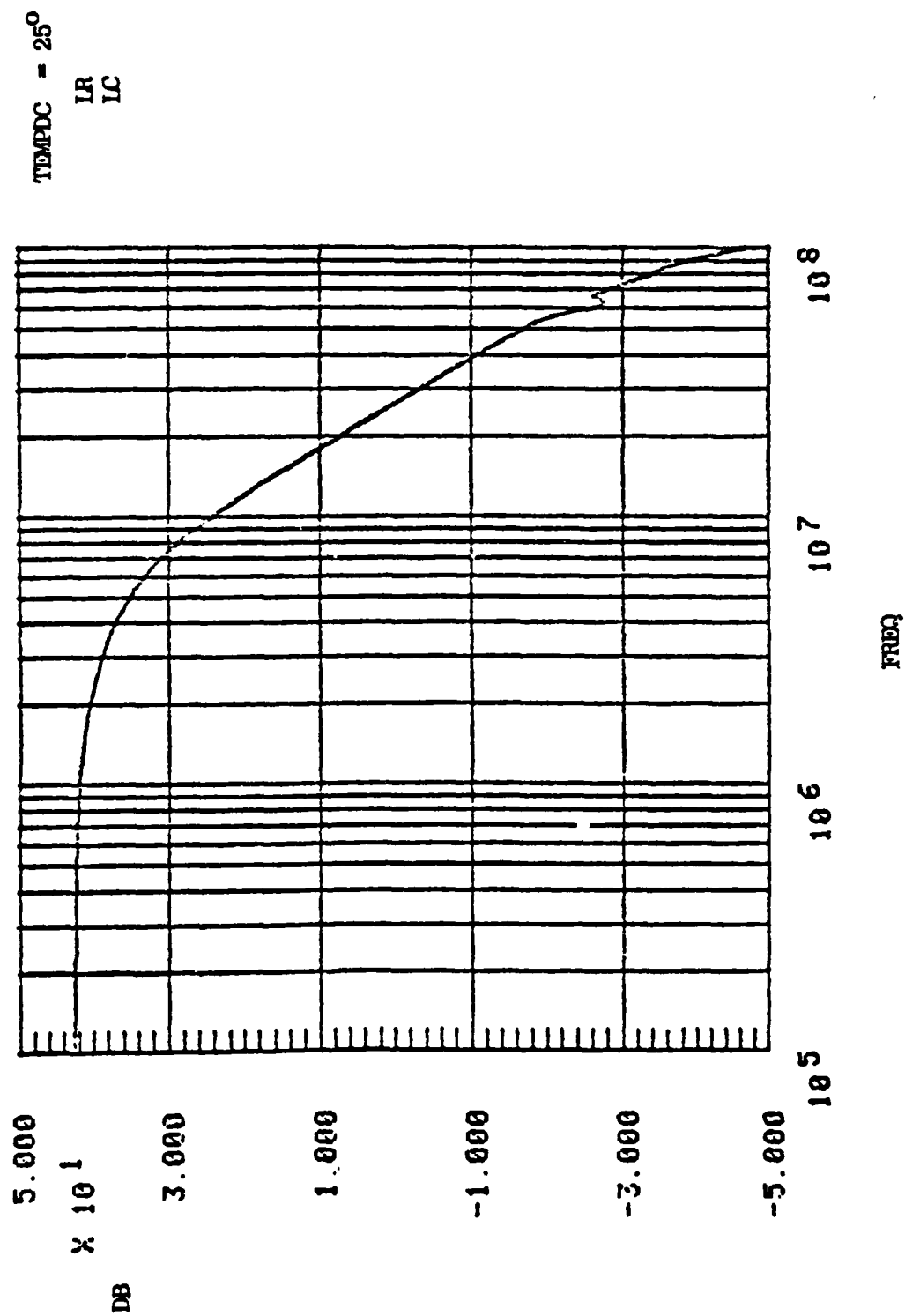
A₁ STEP RESPONSE
100 nA Step



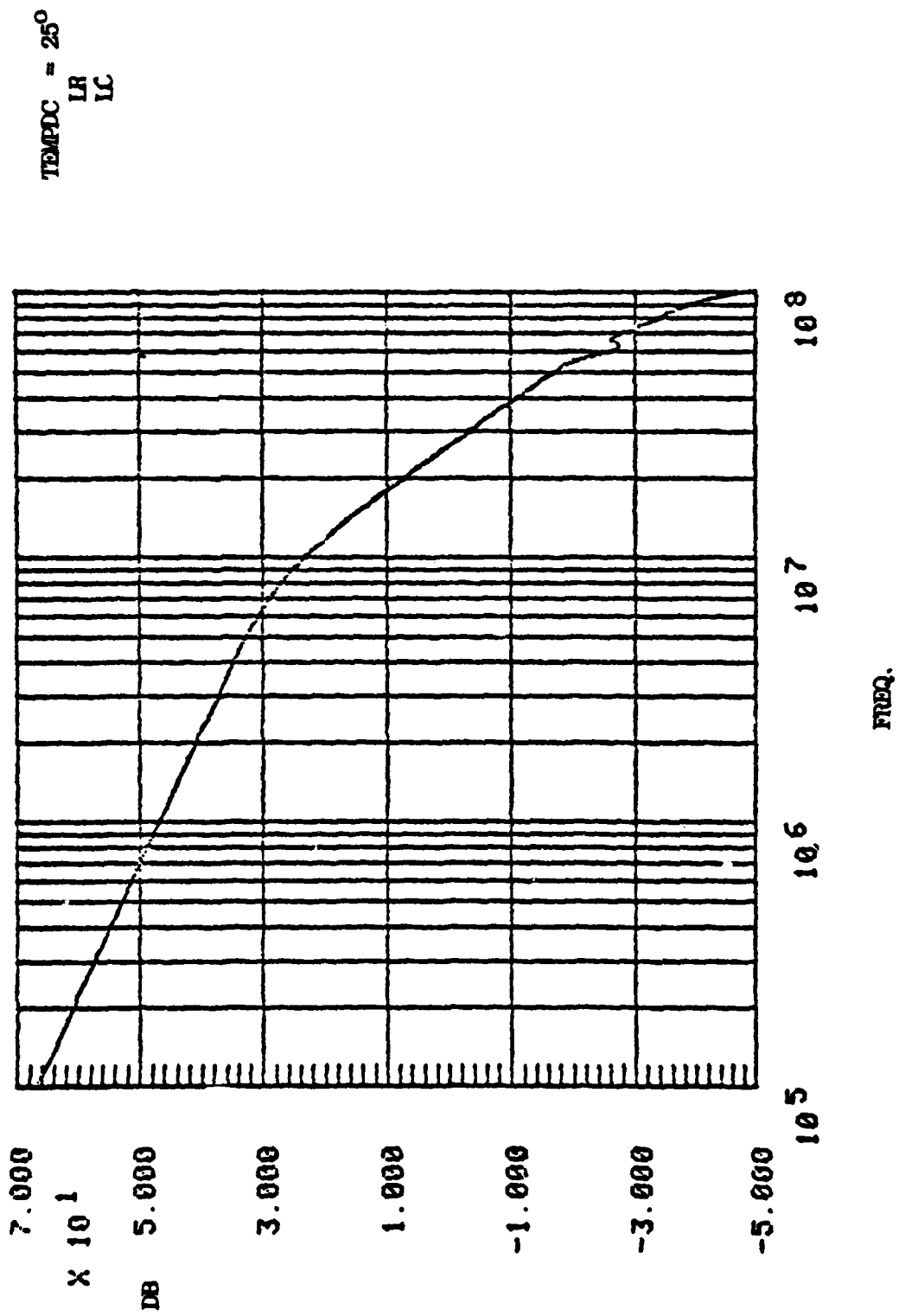
OVERALL GAIN



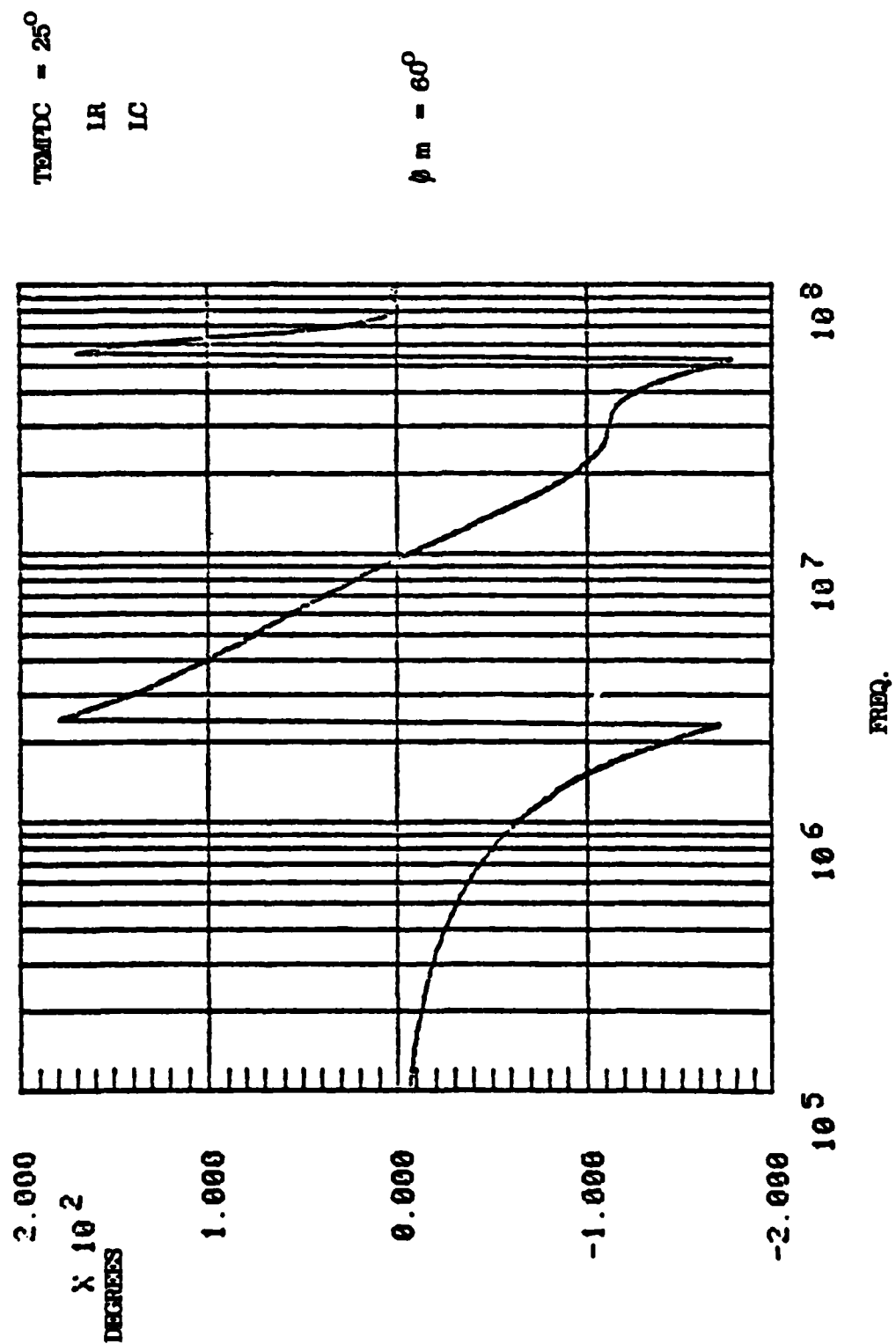
A_2 CLOSED-LOOP GAIN



A₂ OPEN-LOOP GAIN

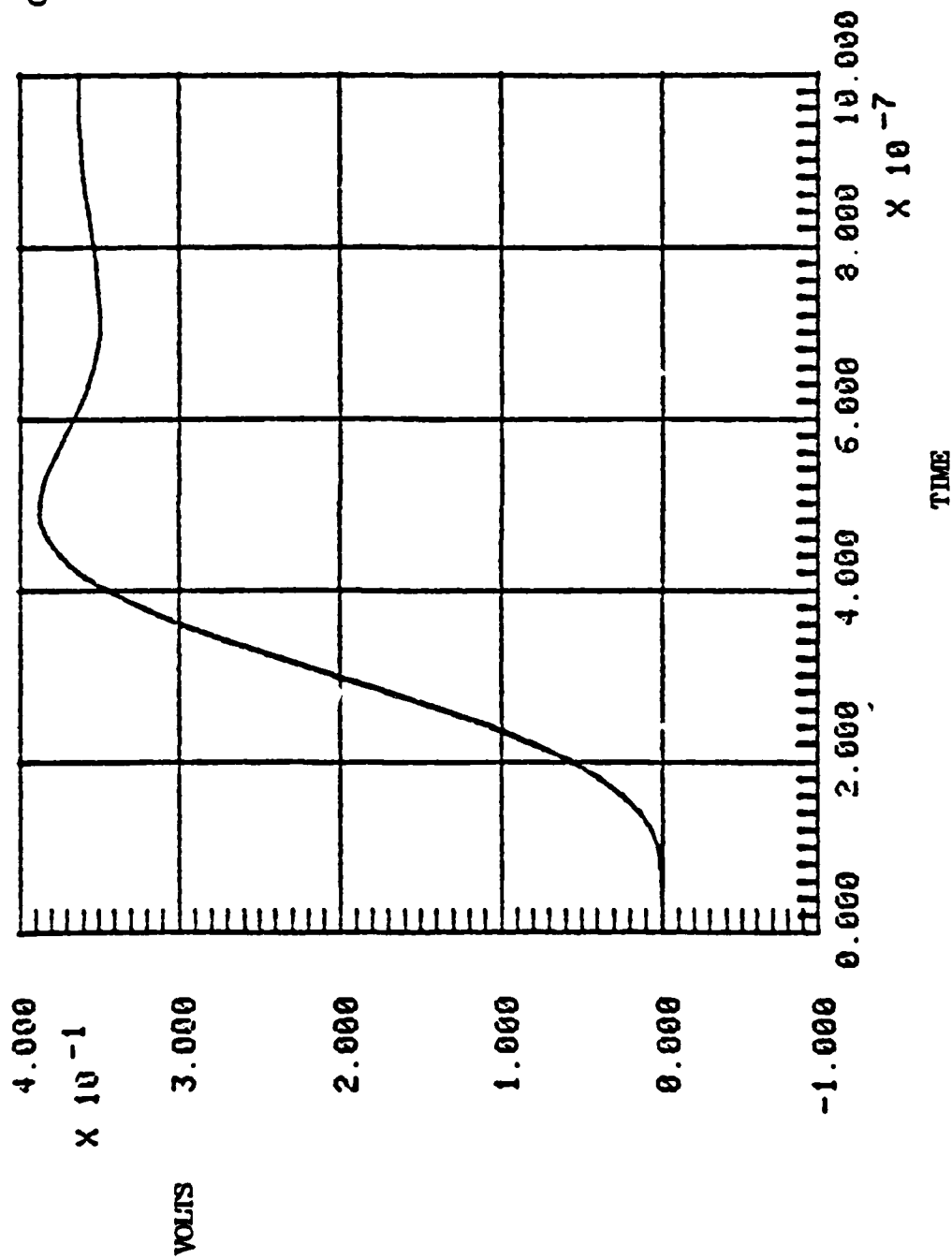


A₂ OPEN-LOOP PHASE

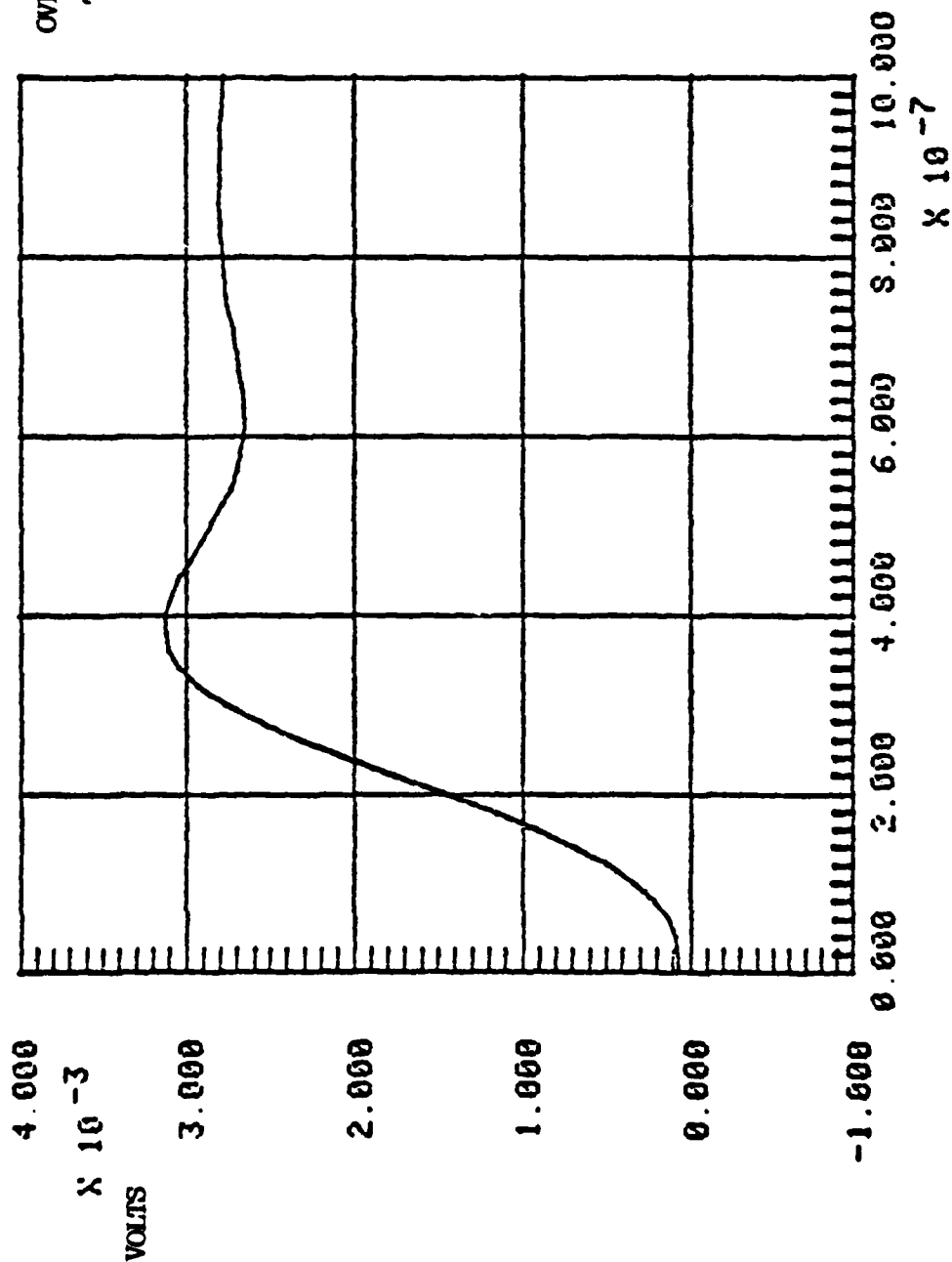


OVERALL STEP RESPONSE

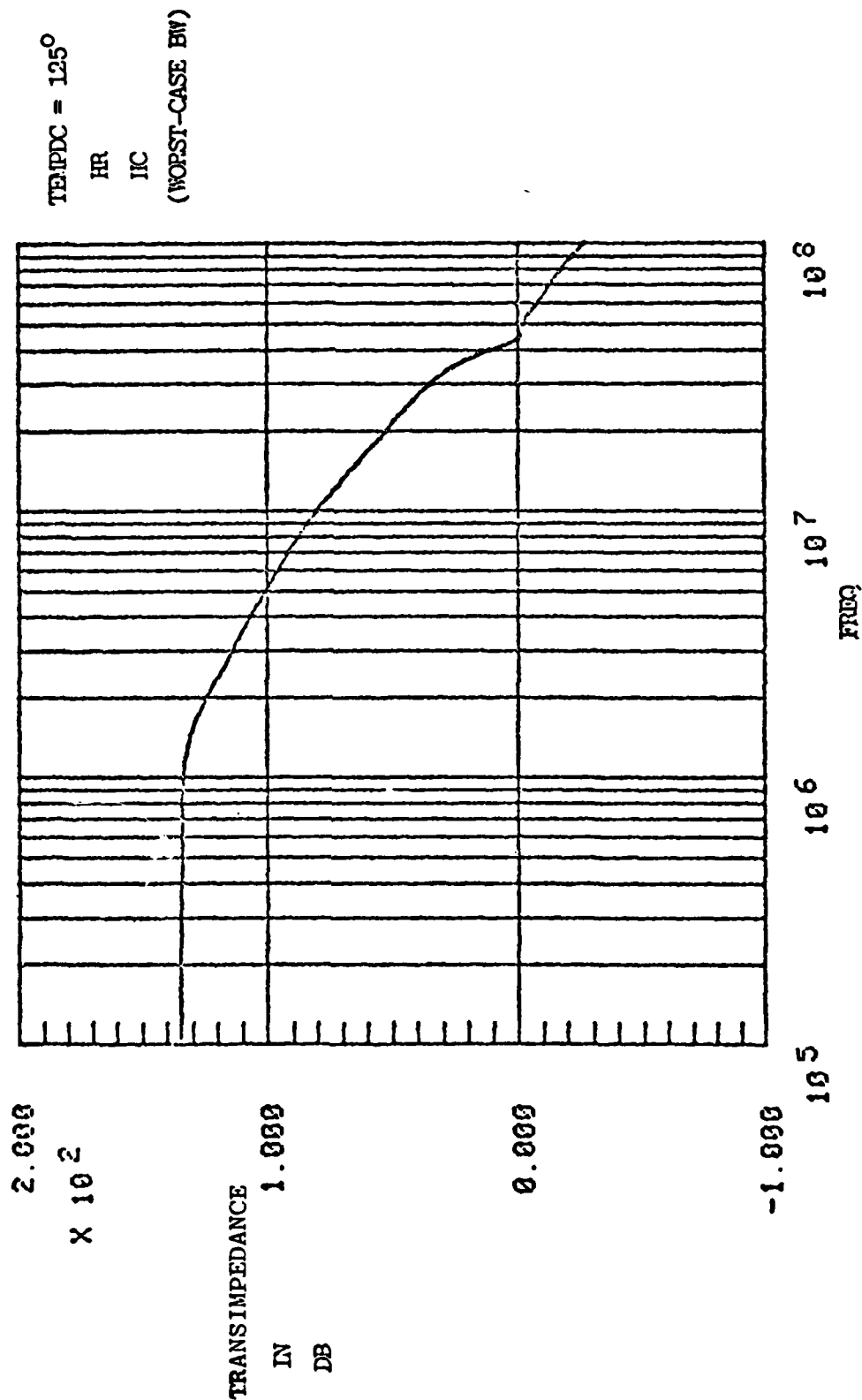
100 nA STEP



A₁ STEP RESPONSE
100 nA STEP



OVERALL GAIN

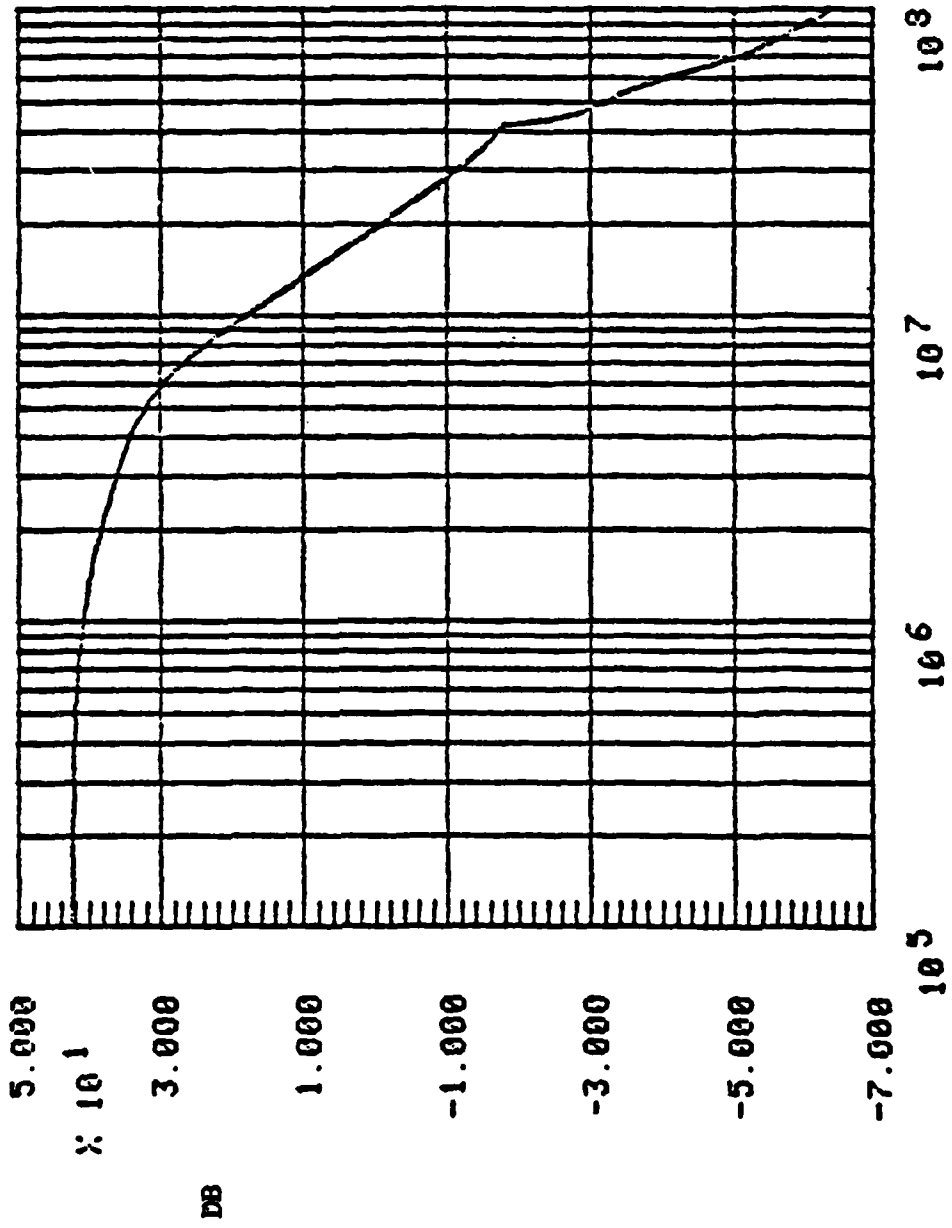


A_2 CLOSED-LOOP GAIN

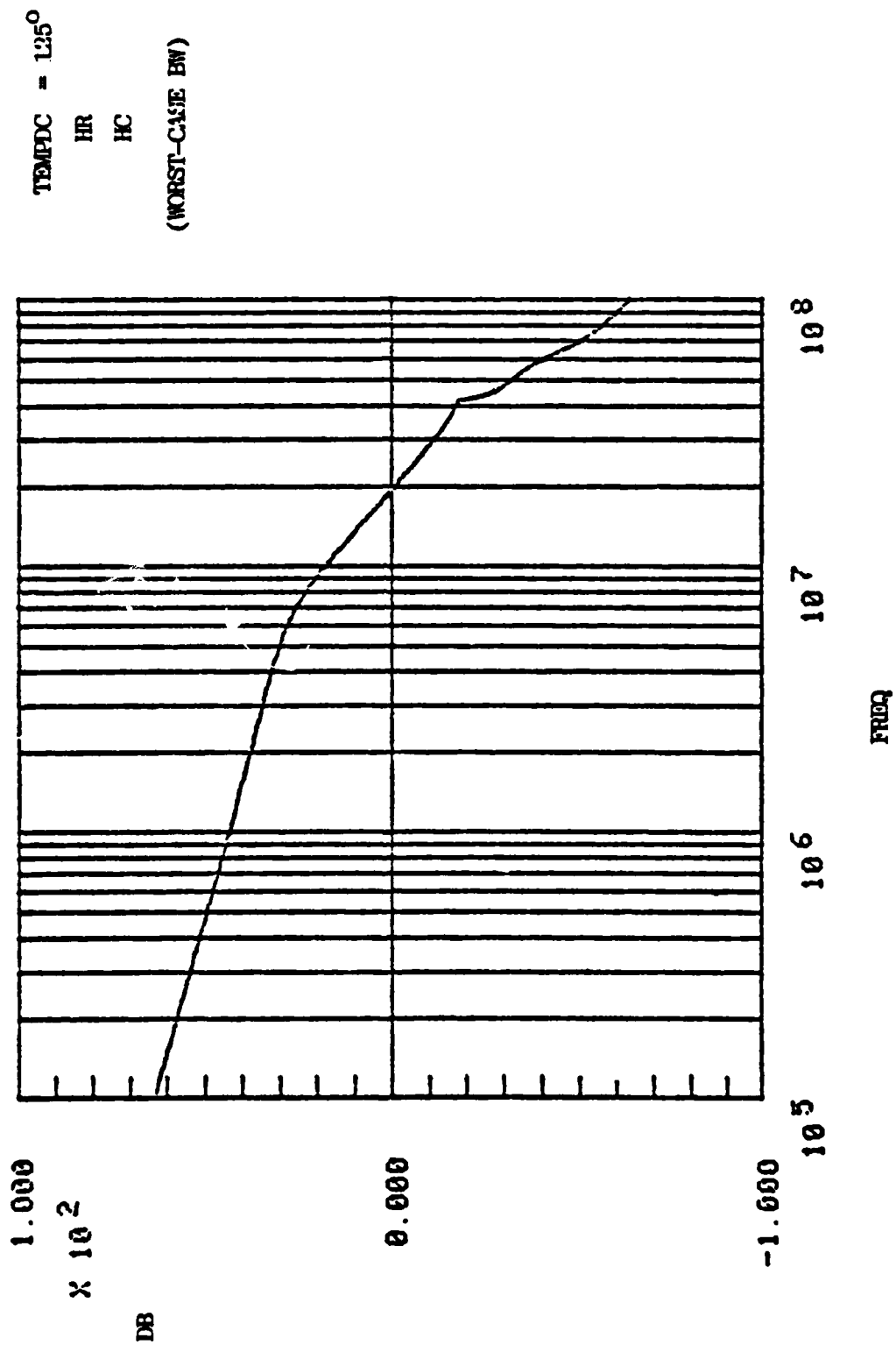
TEMPDC = 125°

HR
HC

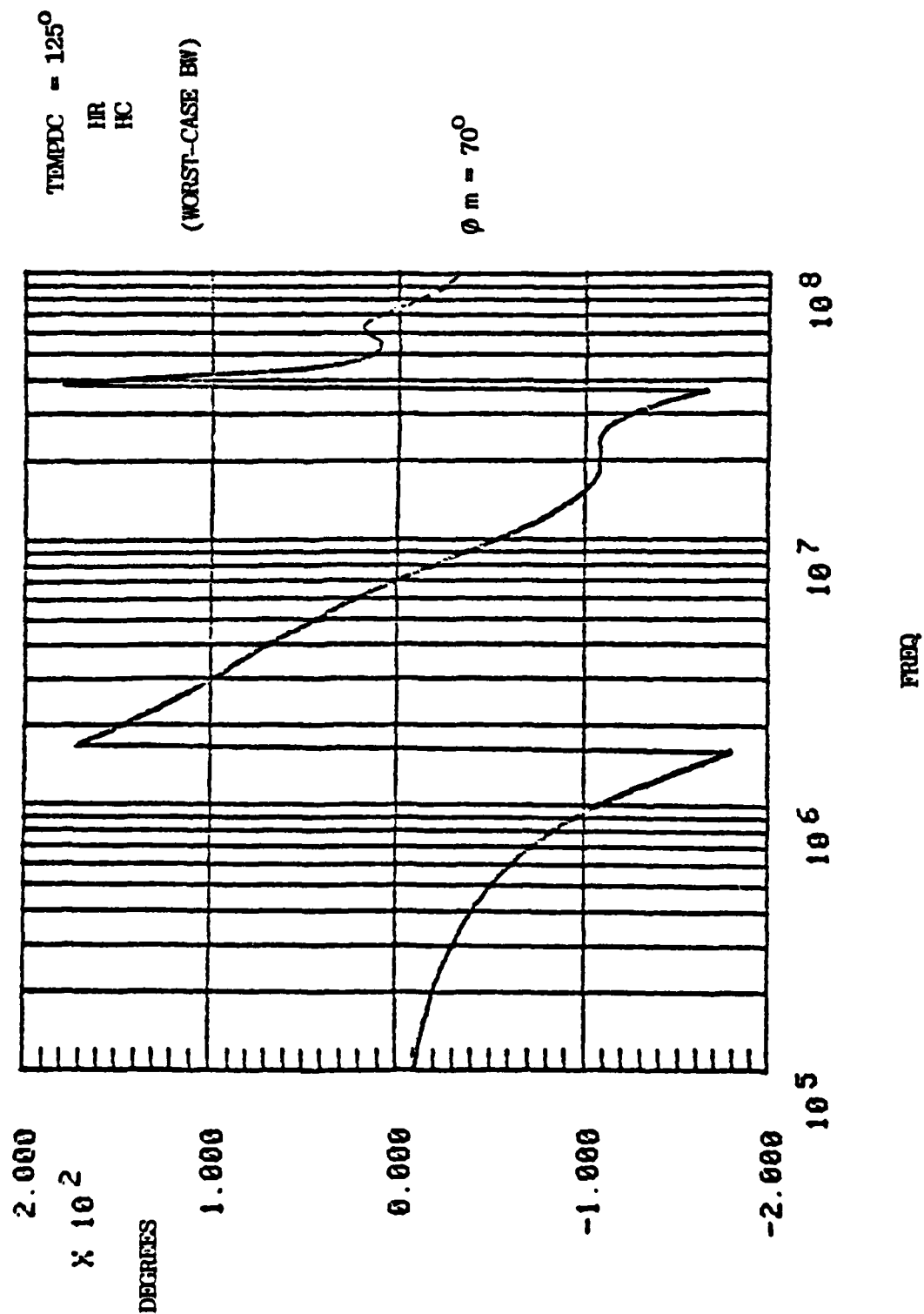
(WORST CASE BW)



A_2 OPEN-LOOP GAIN

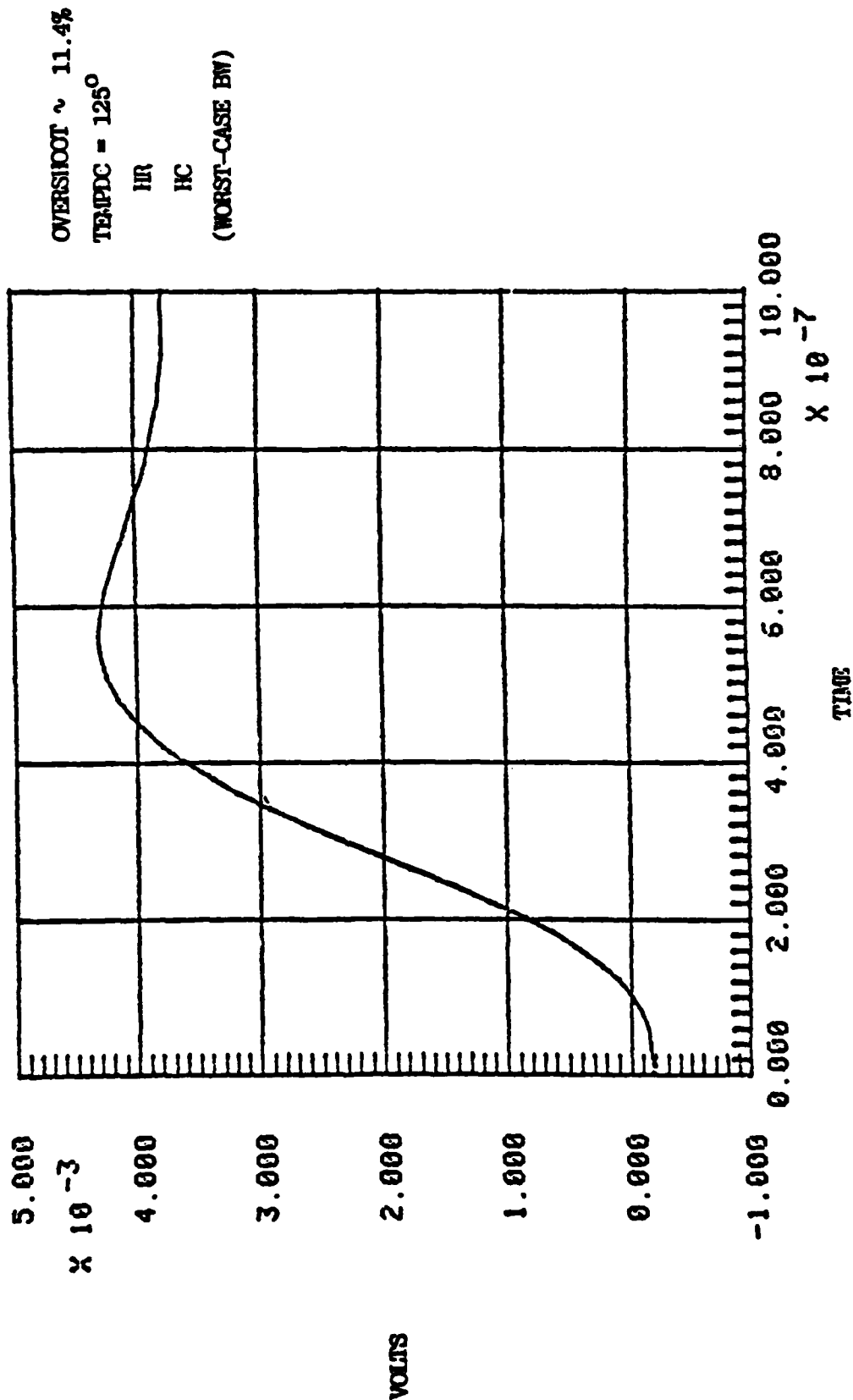


A₂ OPEN-LOOP PHASE



OVERALL STEP RESPONSE

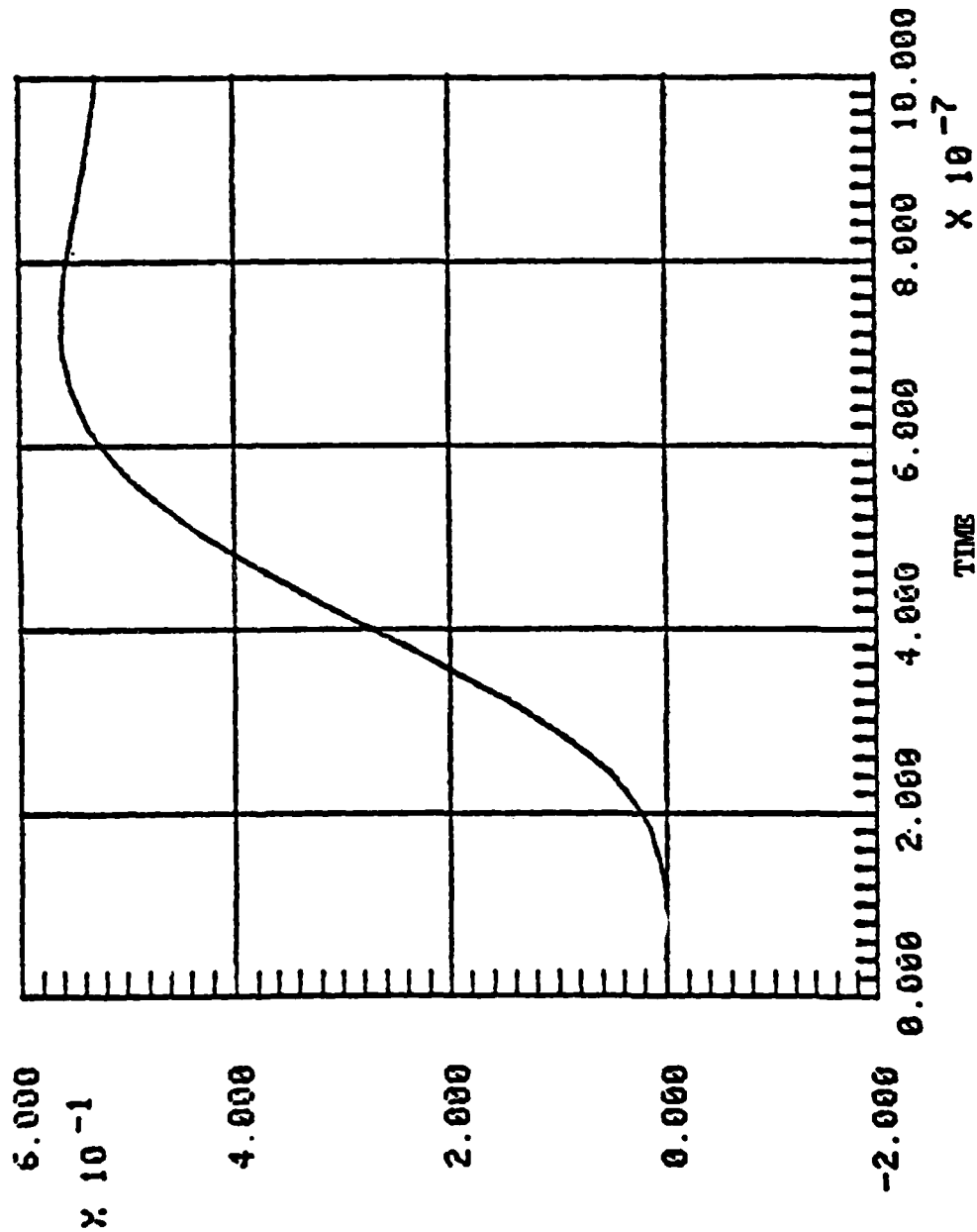
100 NA STEP



A₁ STEP RESPONSE

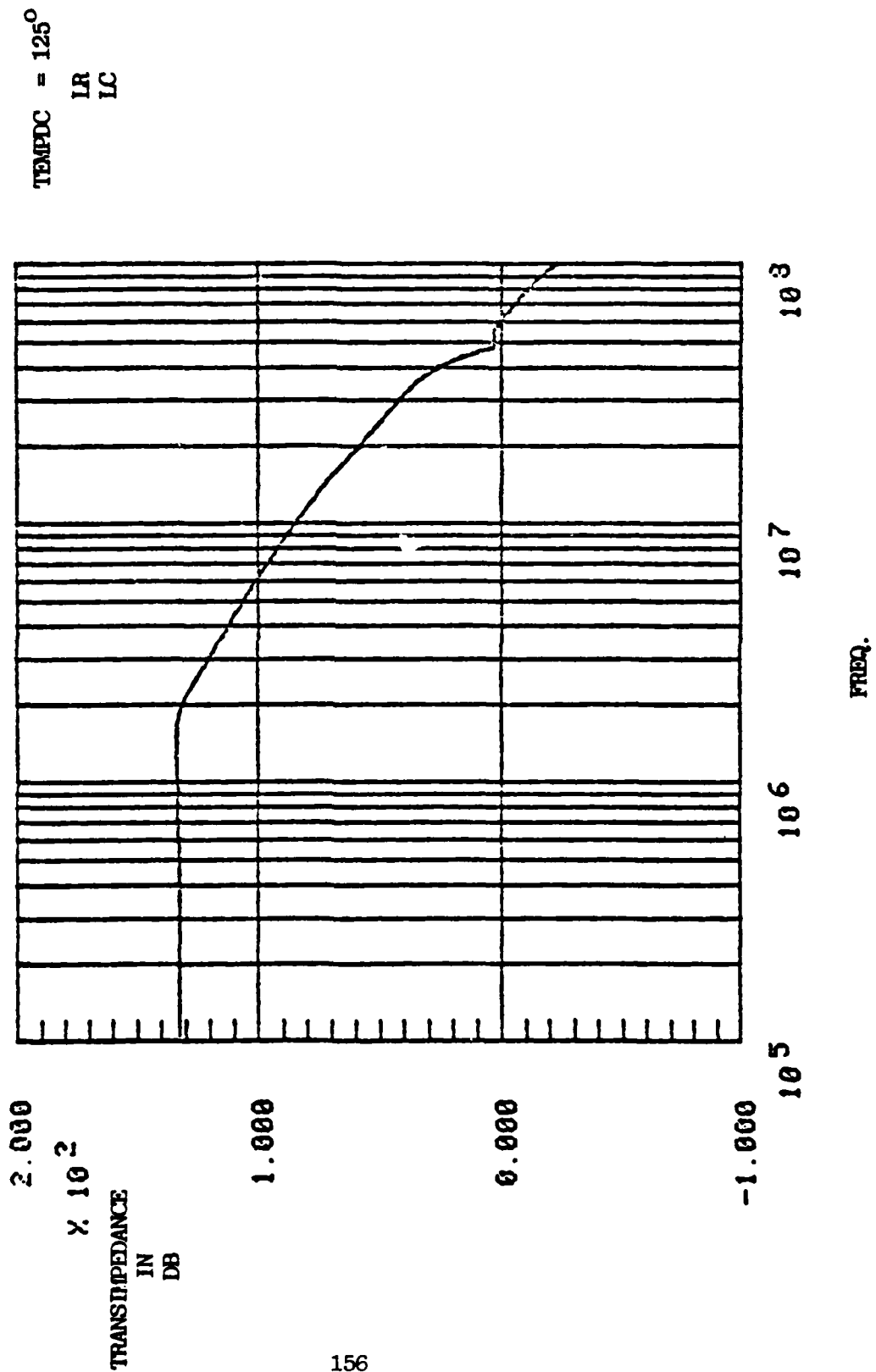
100 NA STEP

OVERSHOOT ~ 12.5%
 TEMPTC = 125
 HR
 HC
 (WORST CASE BM)

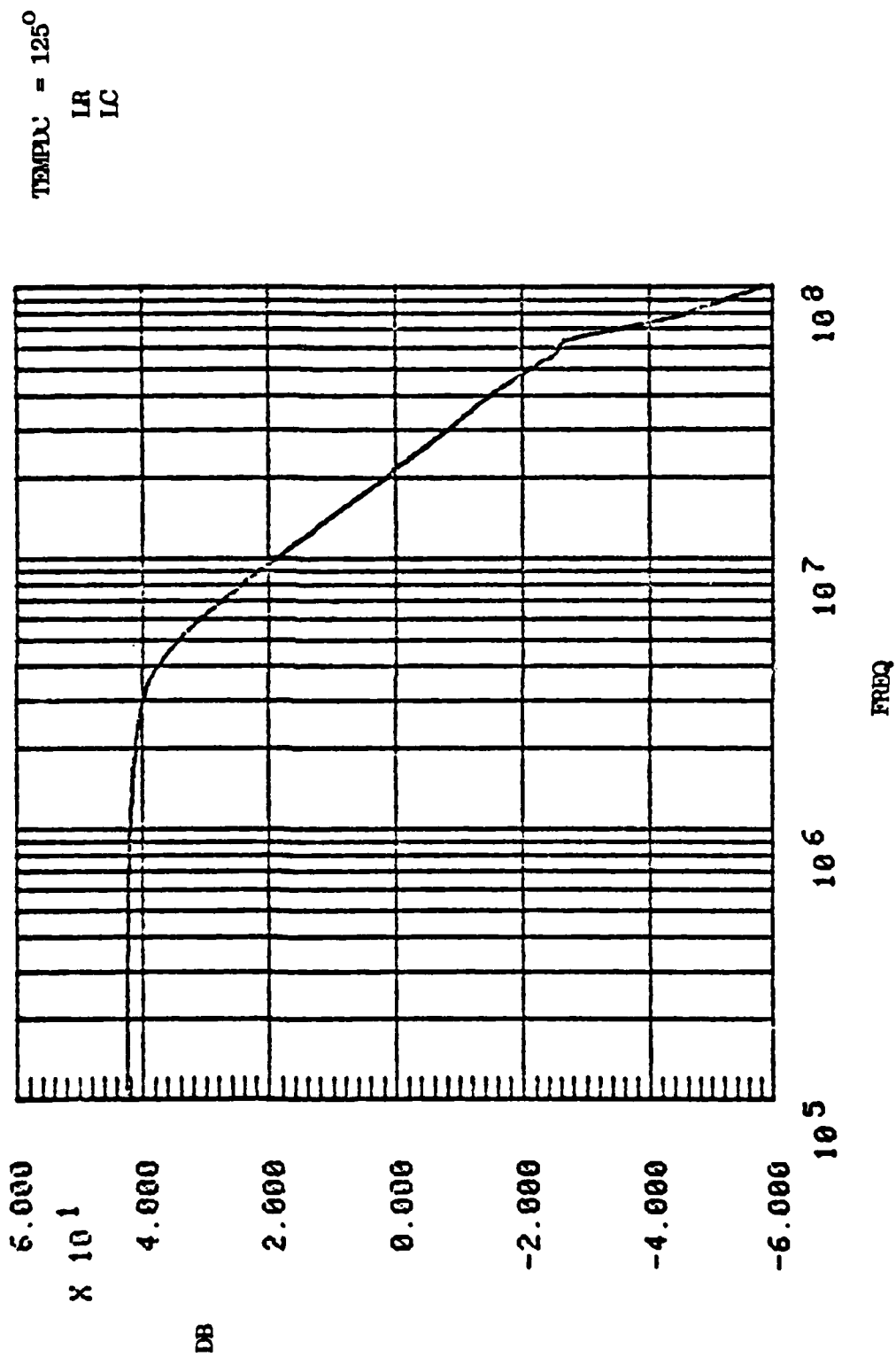


VOLTS

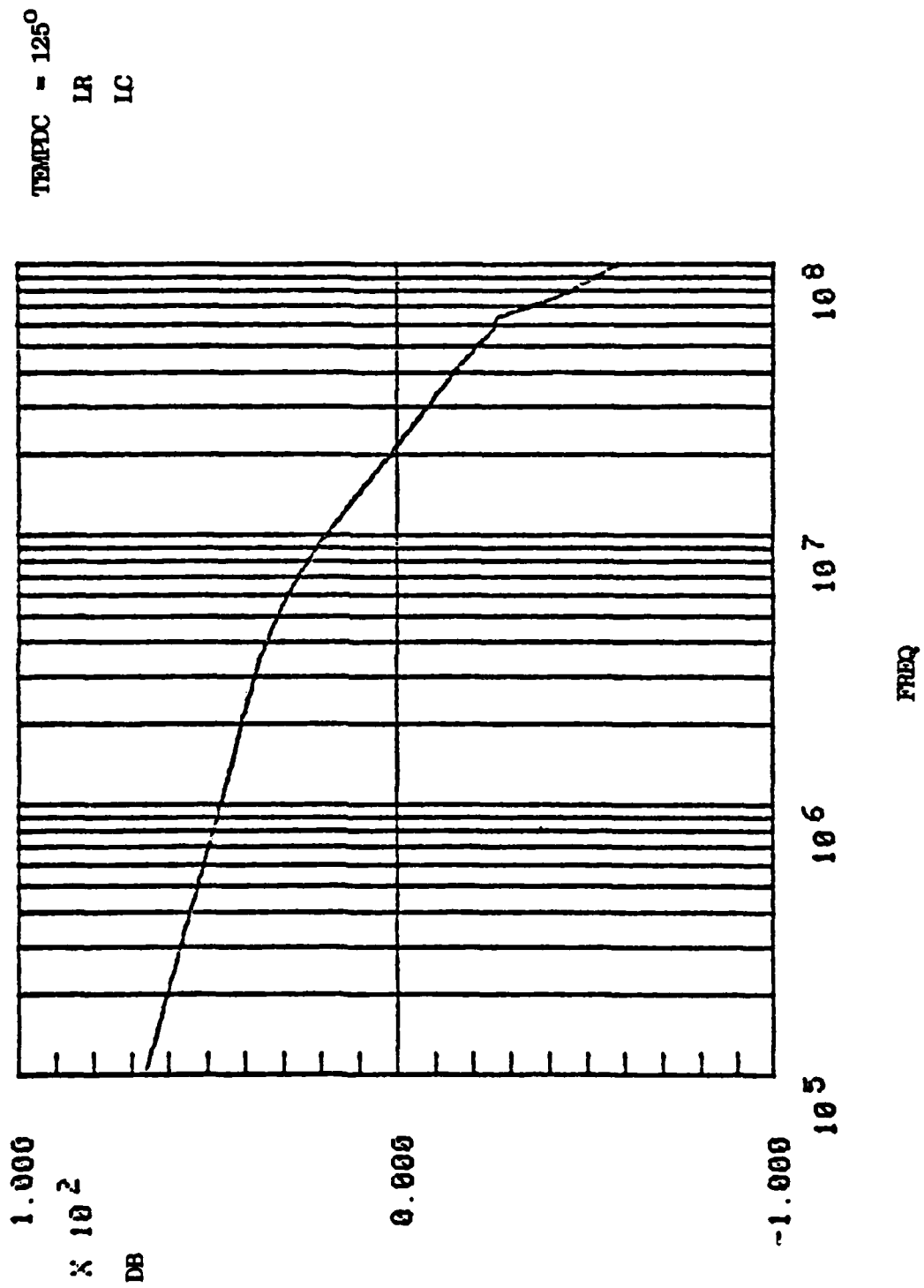
OVERALL GAIN



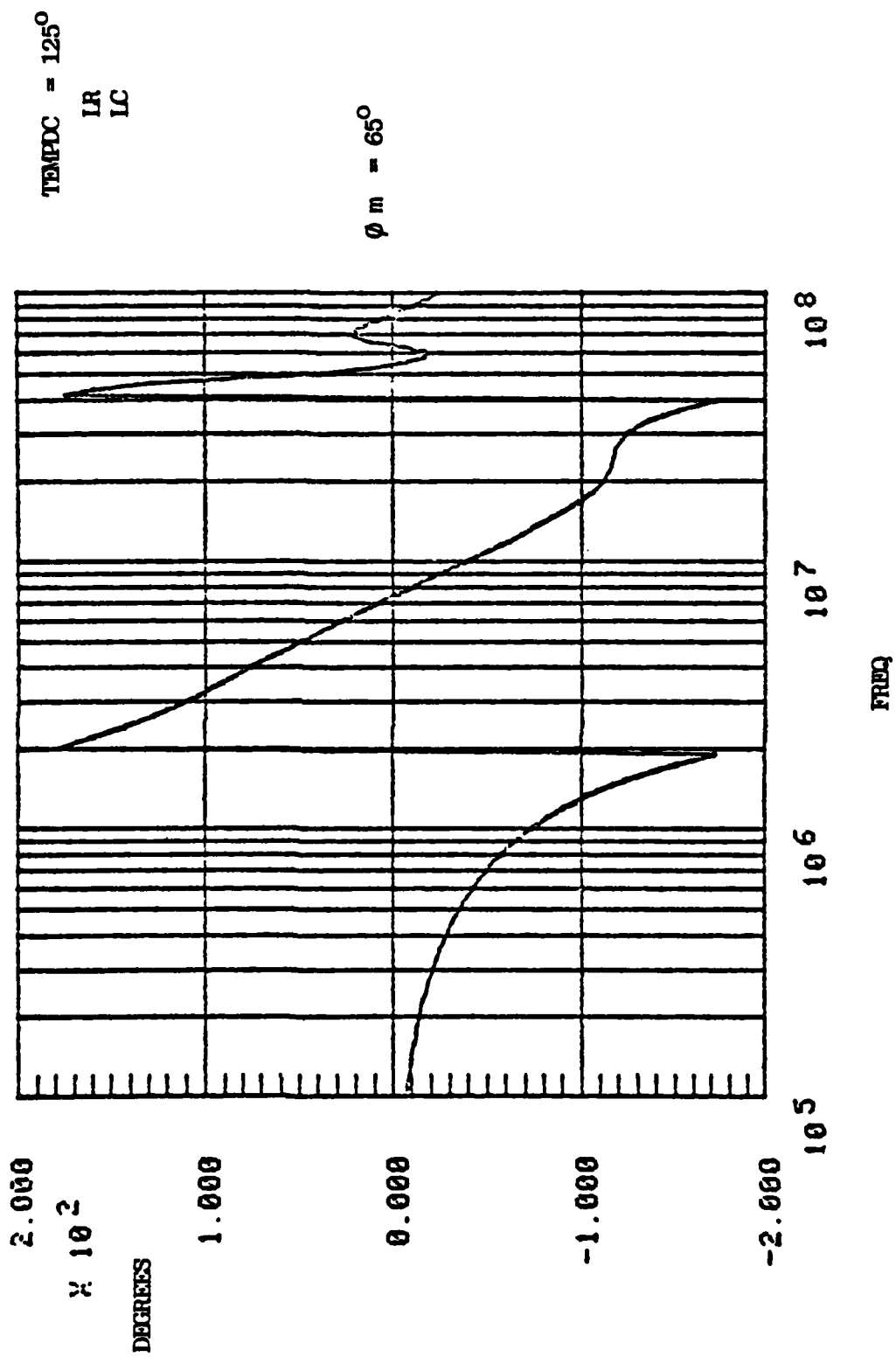
A₂ CLOSED-LOOP GAIN



A₂ OPEN-LOOP GAIN

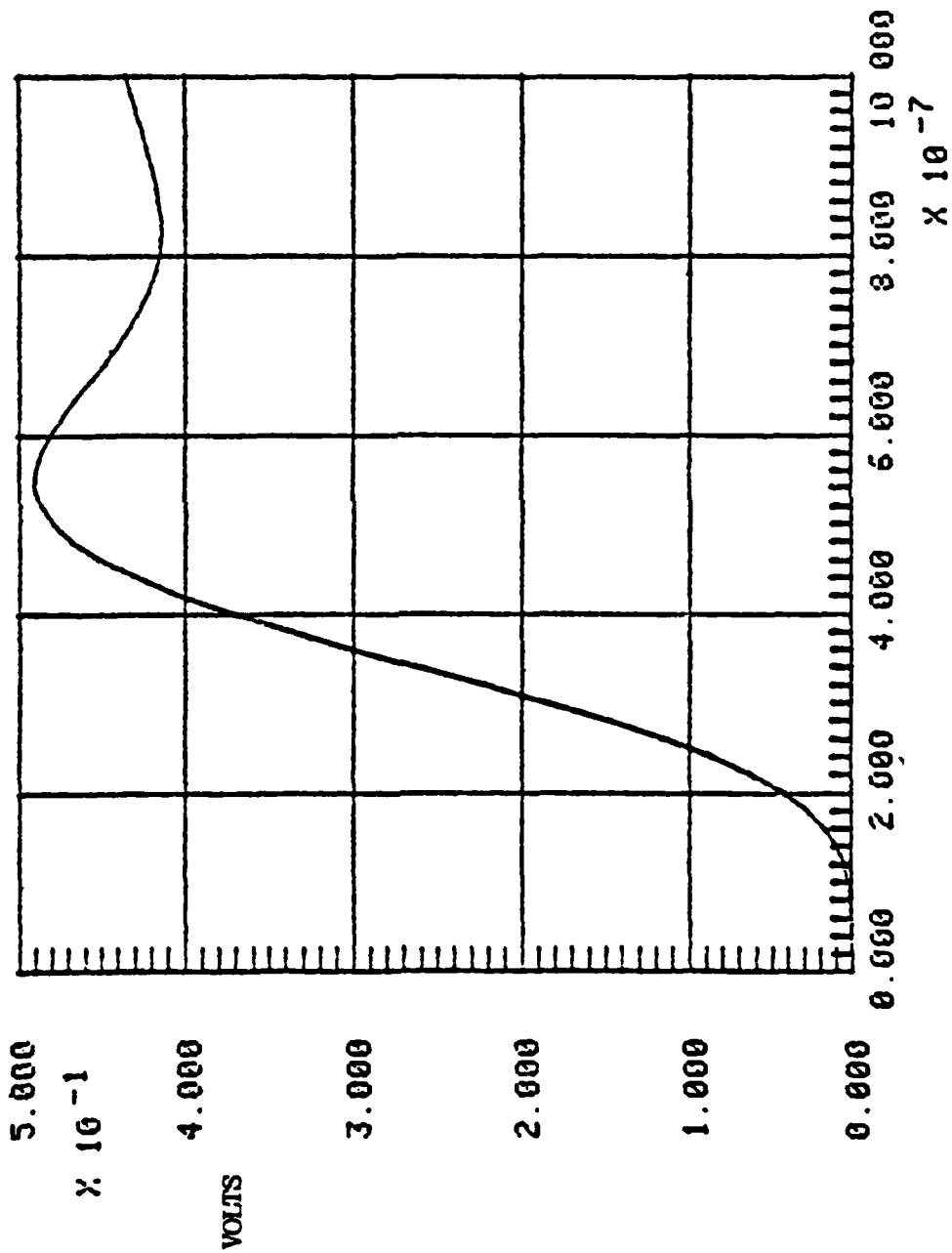


A₂ OPEN-LOOP PHASE



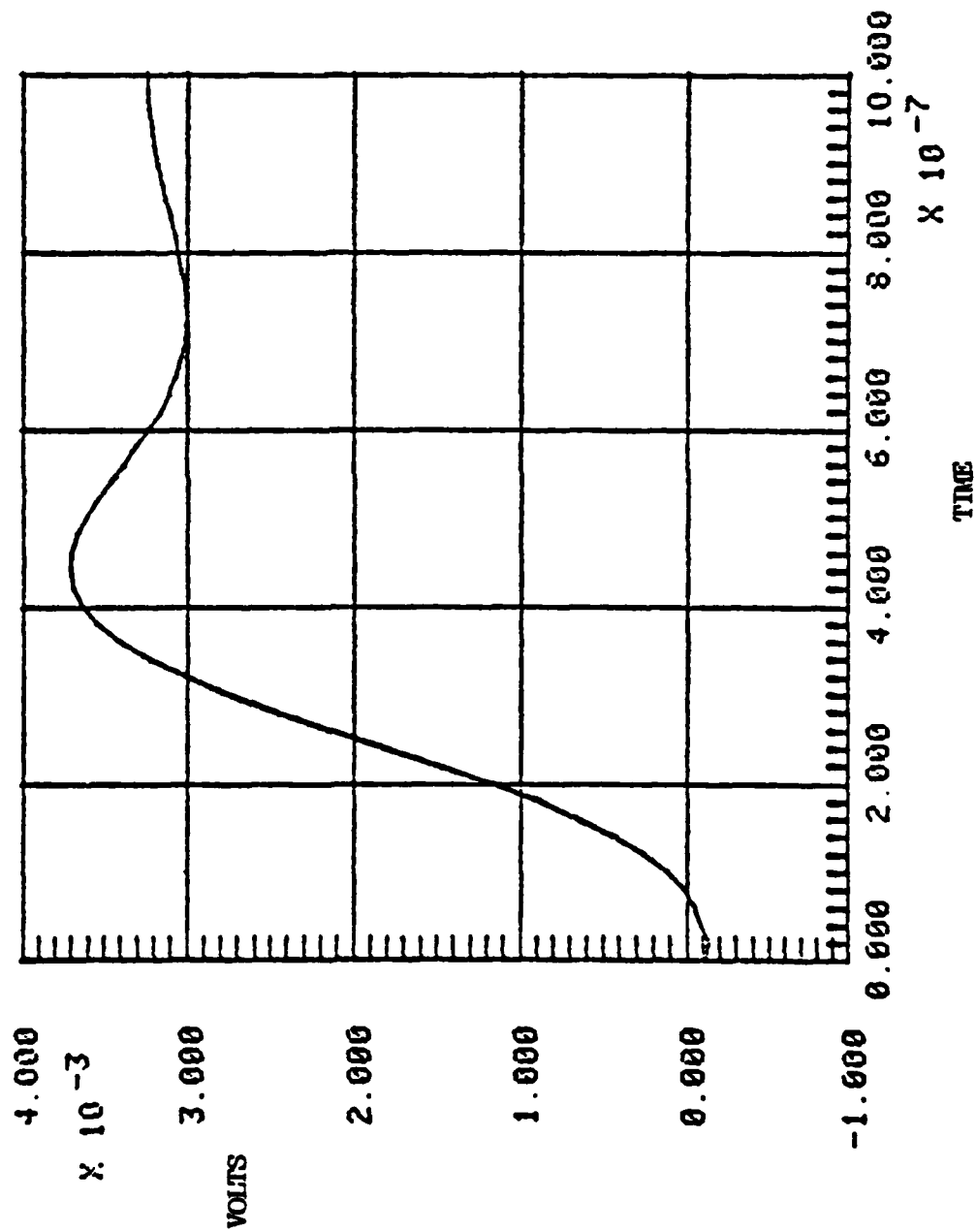
OVERALL STEP RESPONSE

100 NA STEP

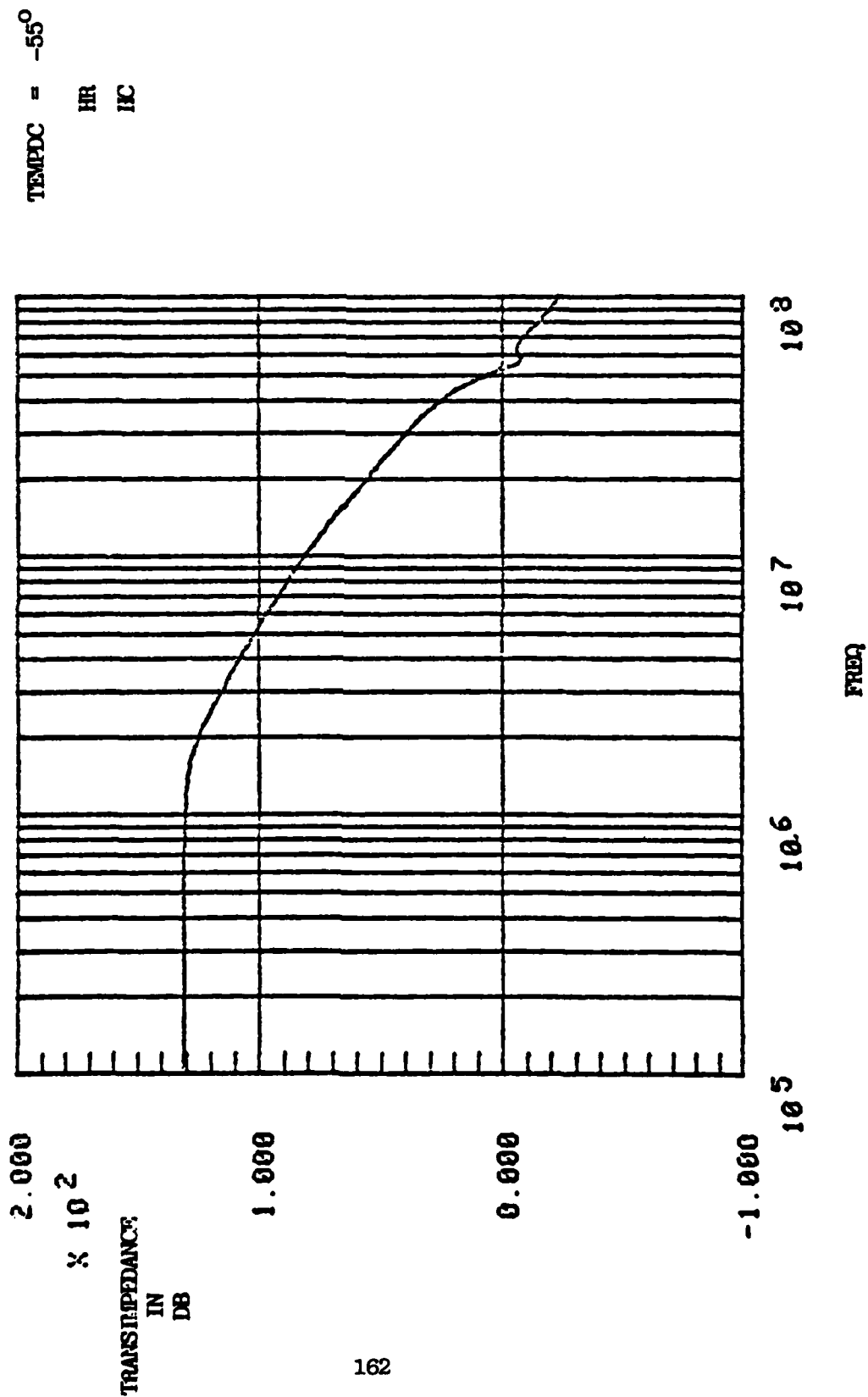


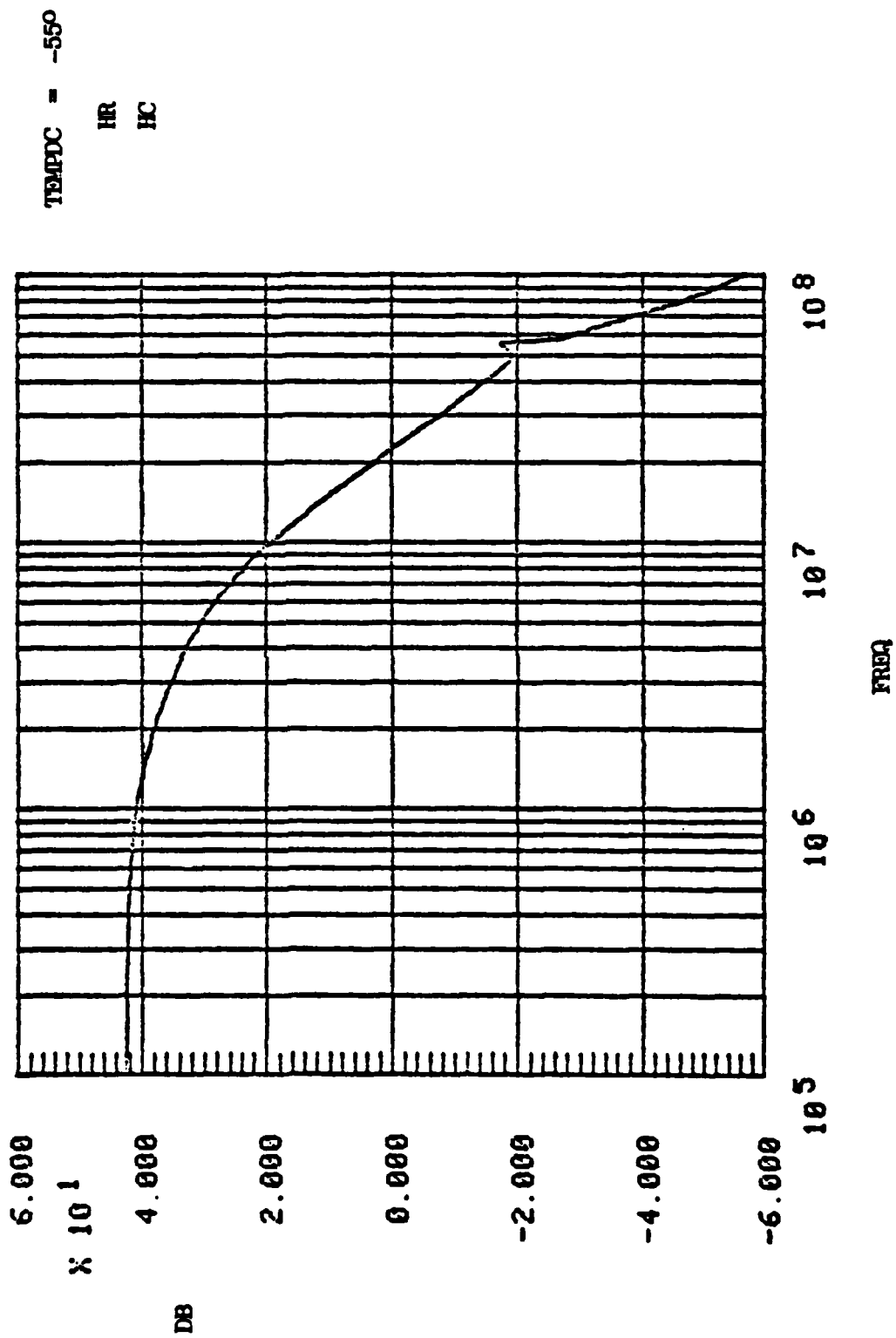
OVERSHOOT $\sim 15.3\%$
 TEMPDC = 125°
 LR
 IC

A₁ STEP REPOSE

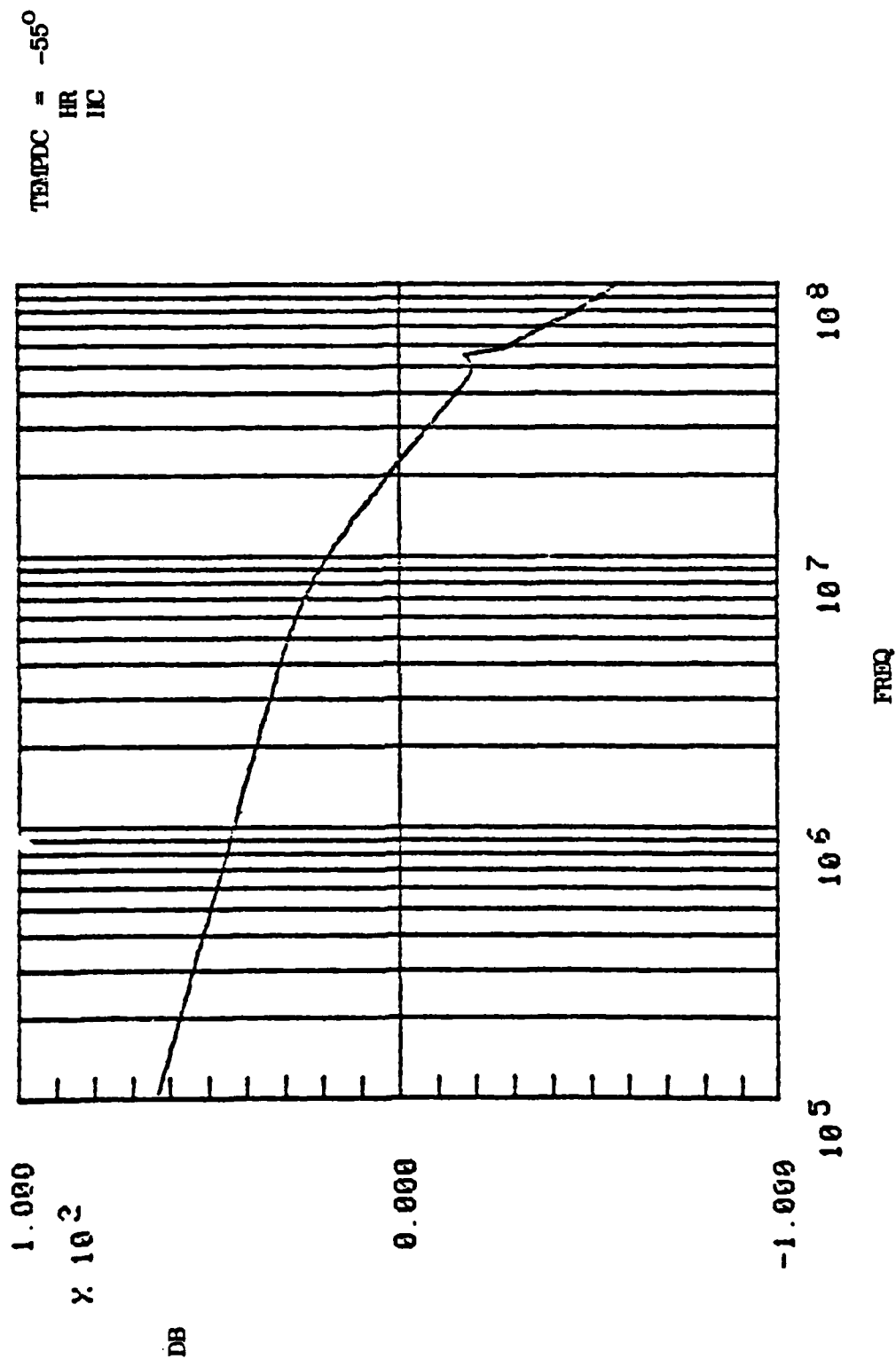


OVERALL GAIN

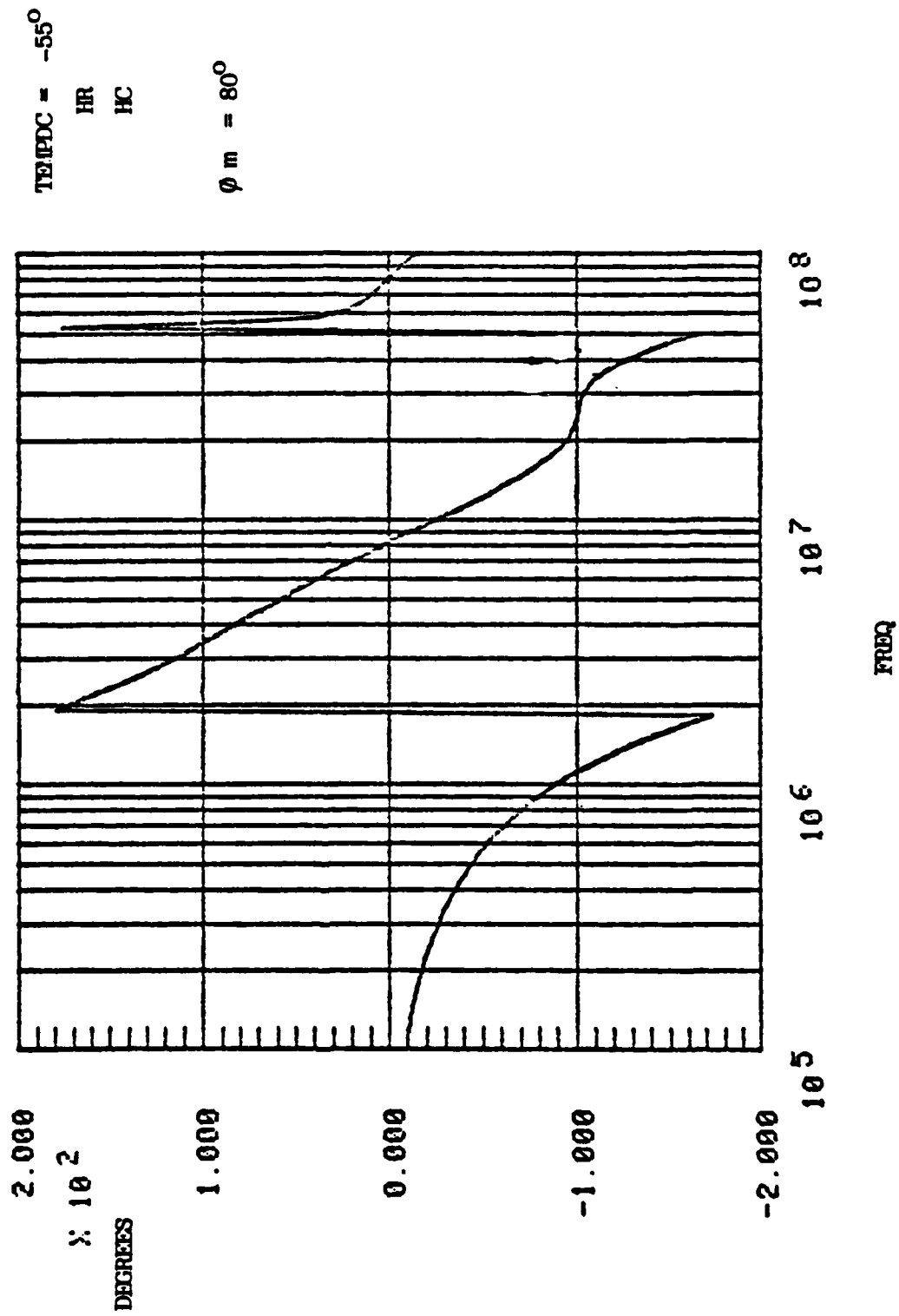


A_2 CLOSED-LOOP GAIN

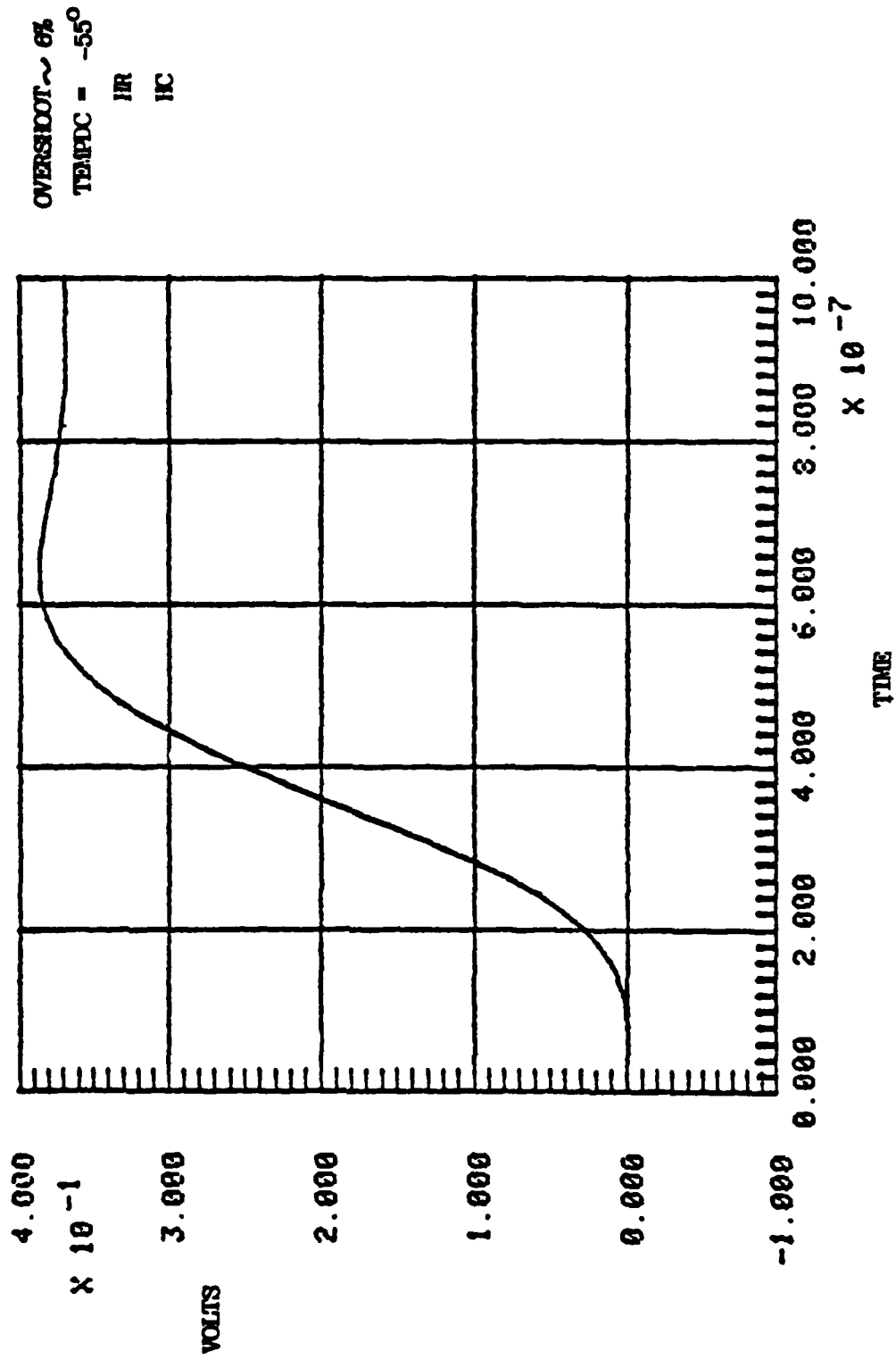
A₂ OPEN-LOOP GAIN



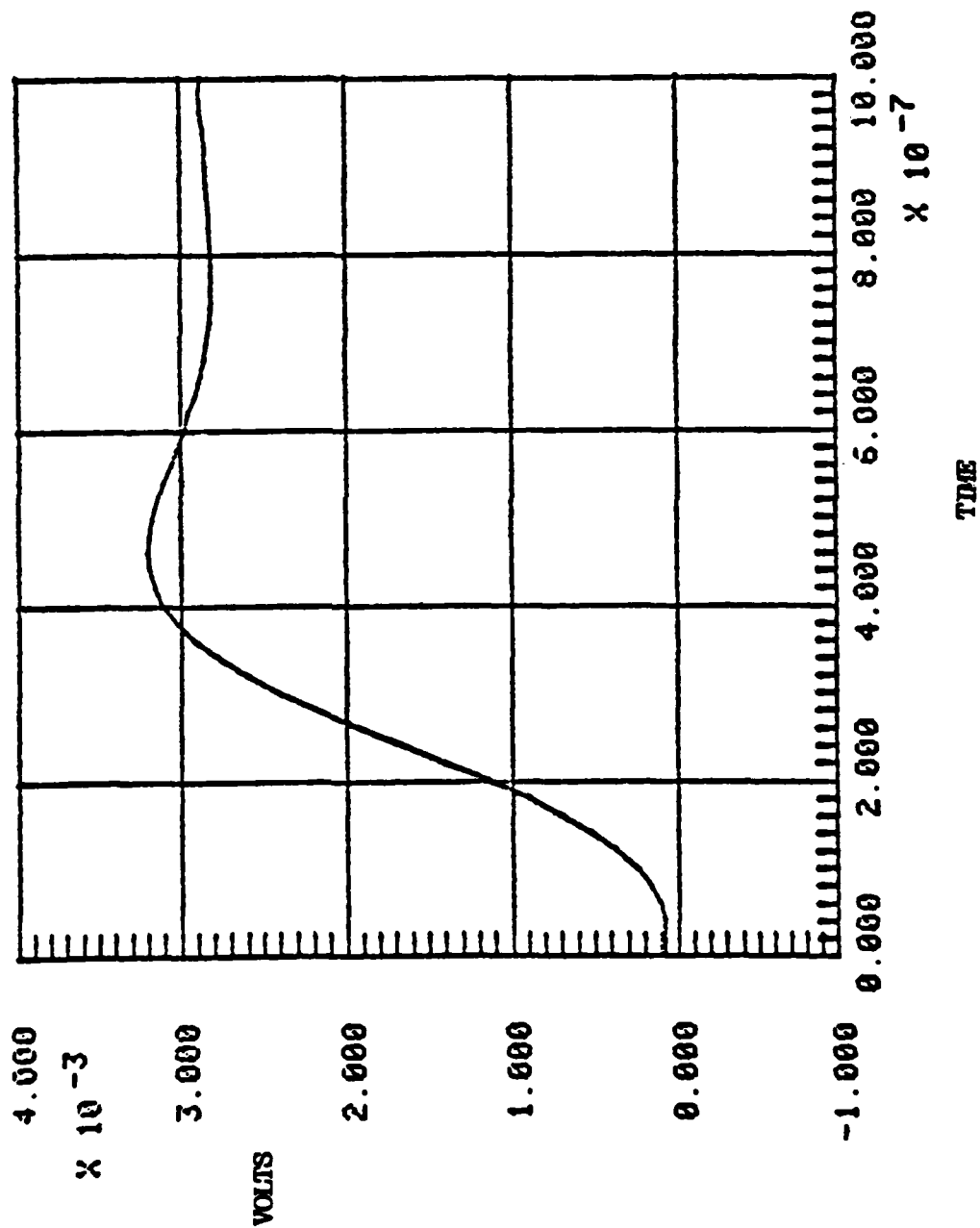
A₂ OPEN-LOOP PHASE



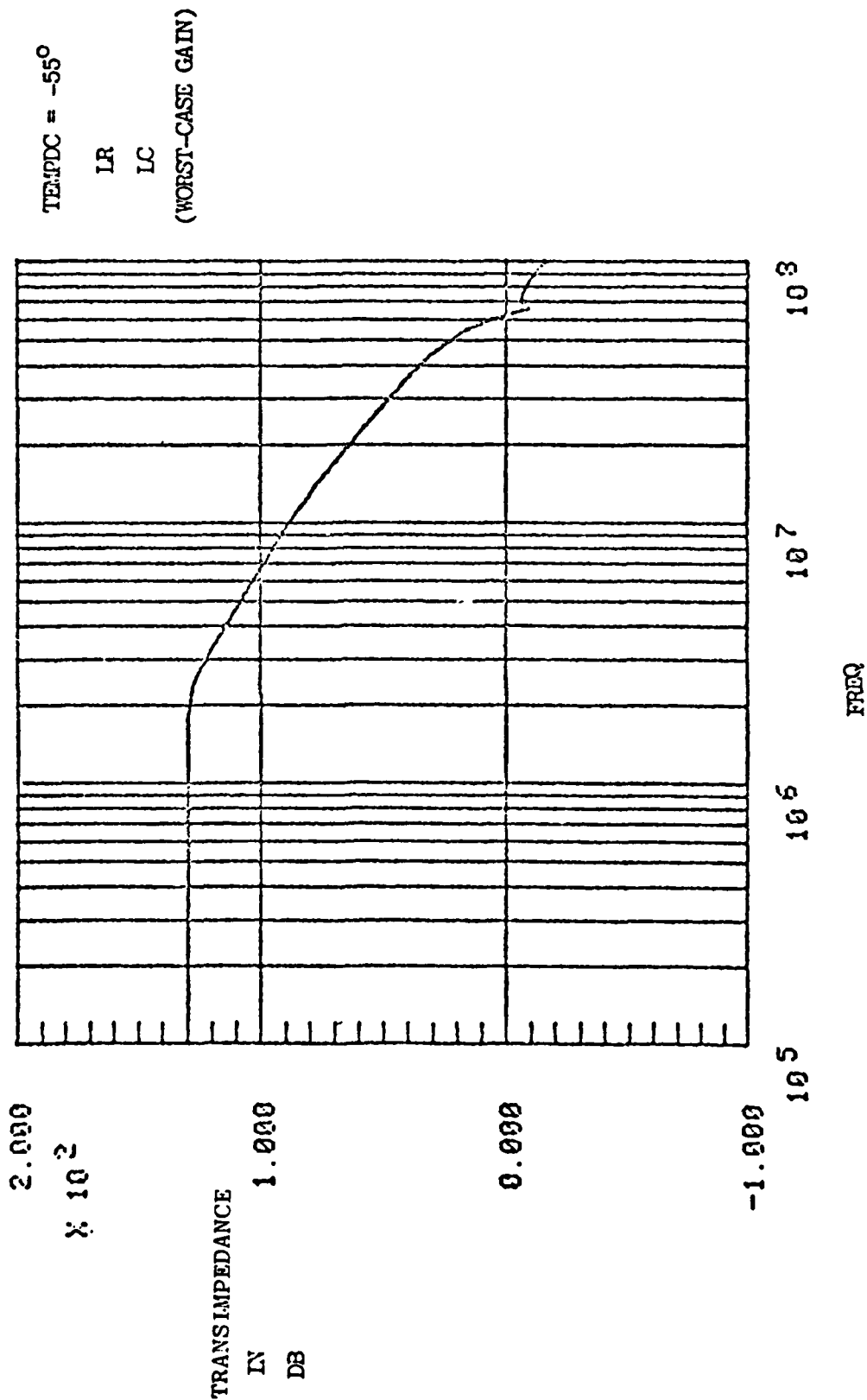
OVERALL STEP RESPONSE
100 NA STEP



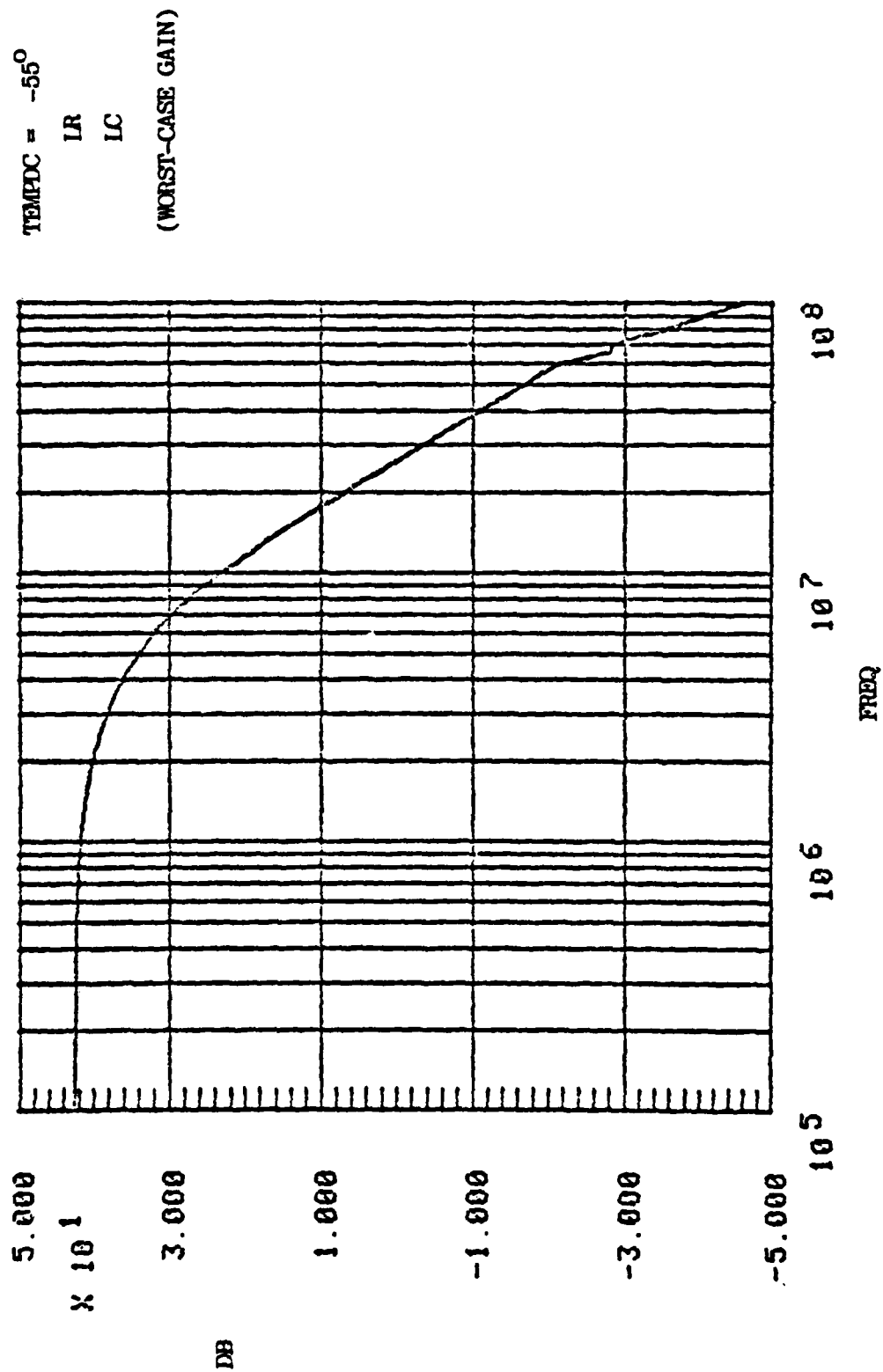
A₁ STEP RESPONSE
100 NA STEP



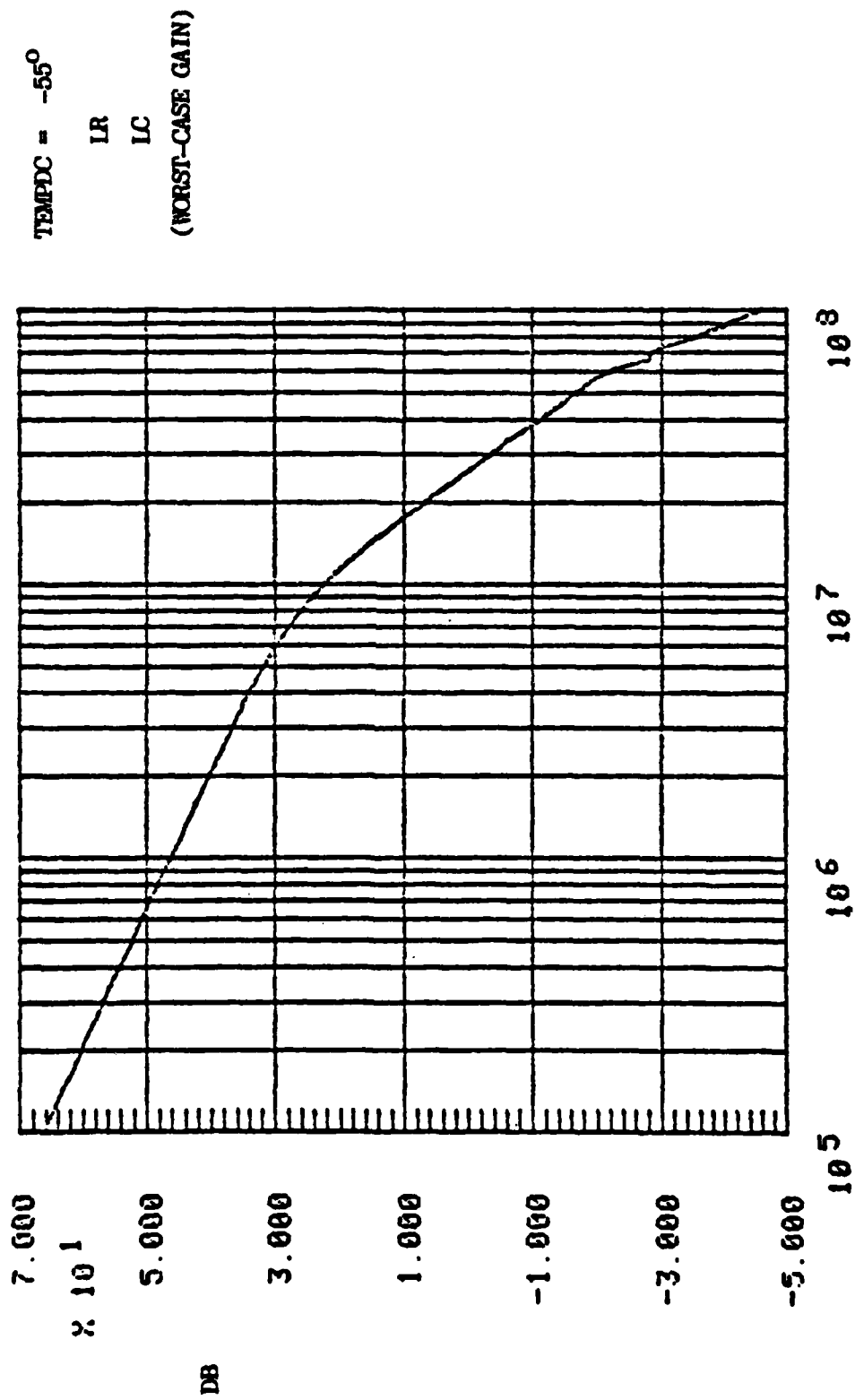
OVERALL GAIN



A₂ CLOSE-LOOP GAIN



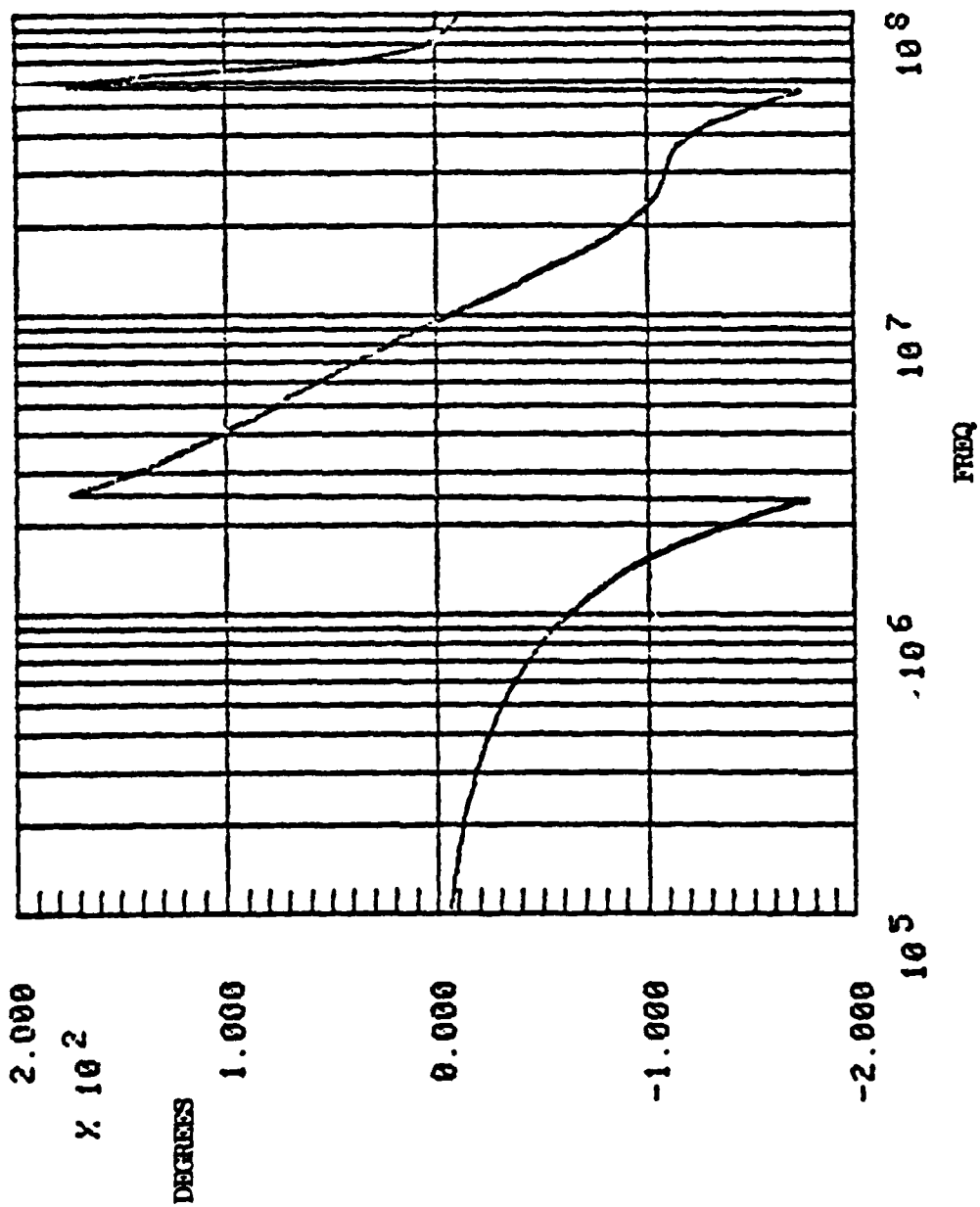
A₂ OPEN-LOOP GAIN



A₂ OPEN-LOOP PHASE

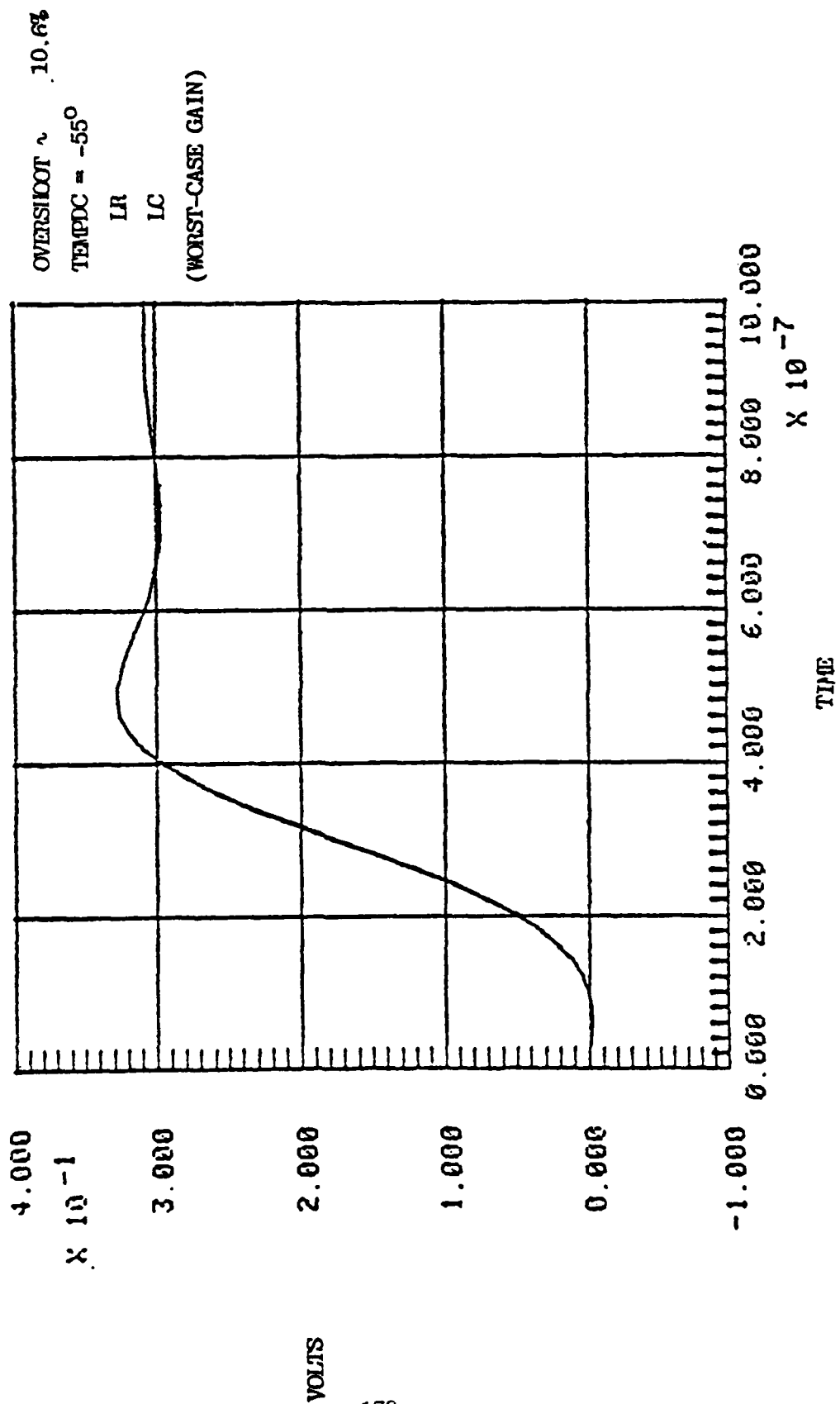
TEMPDC = -55°
 LR
 LC
 (WORST-CASE GAIN)

$\phi_m = 70^\circ$



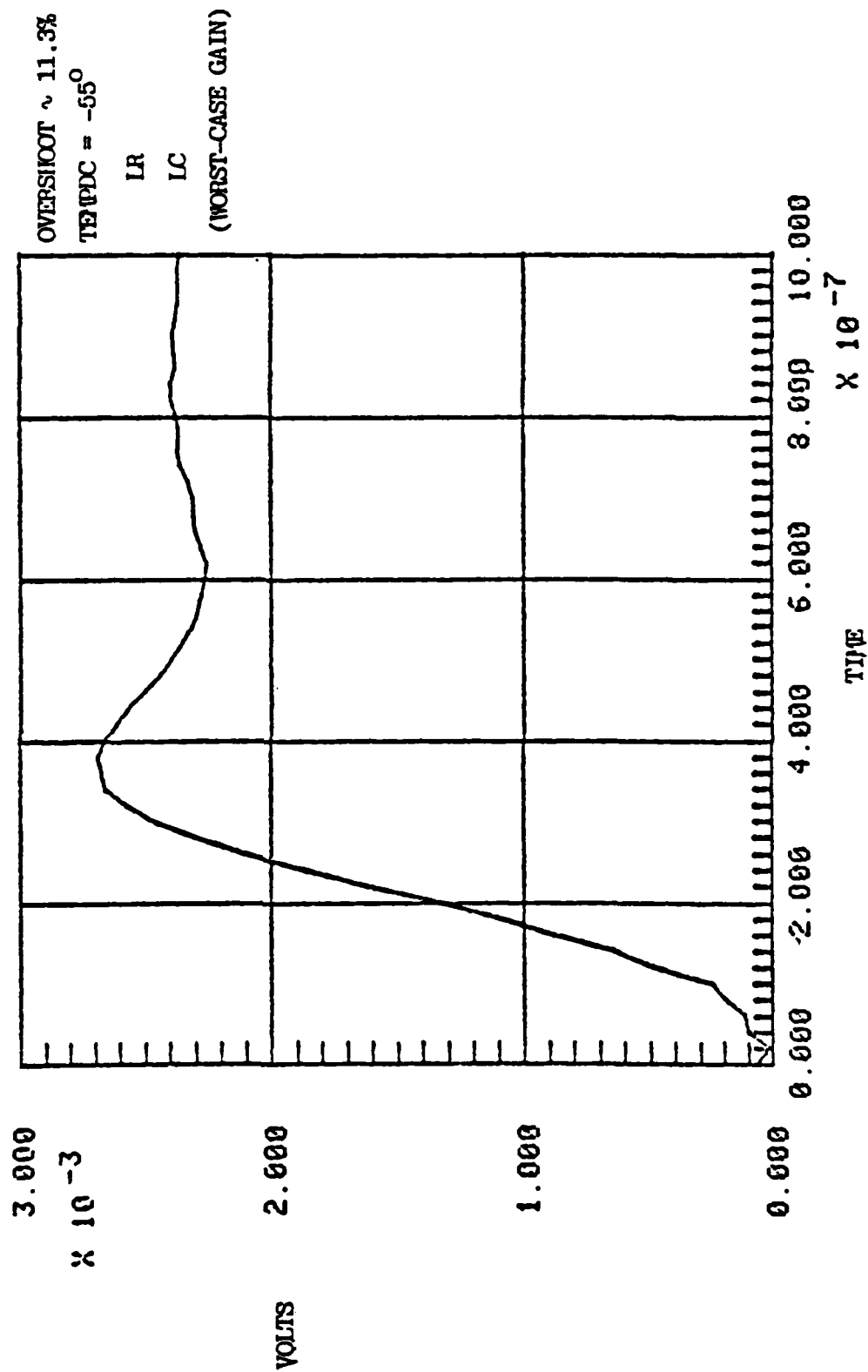
OVERALL STEP RESPONSE

100 NA STEP



A₁ STEP RESPONSE

100 NA STEP



OVERALL GAIN

2.000

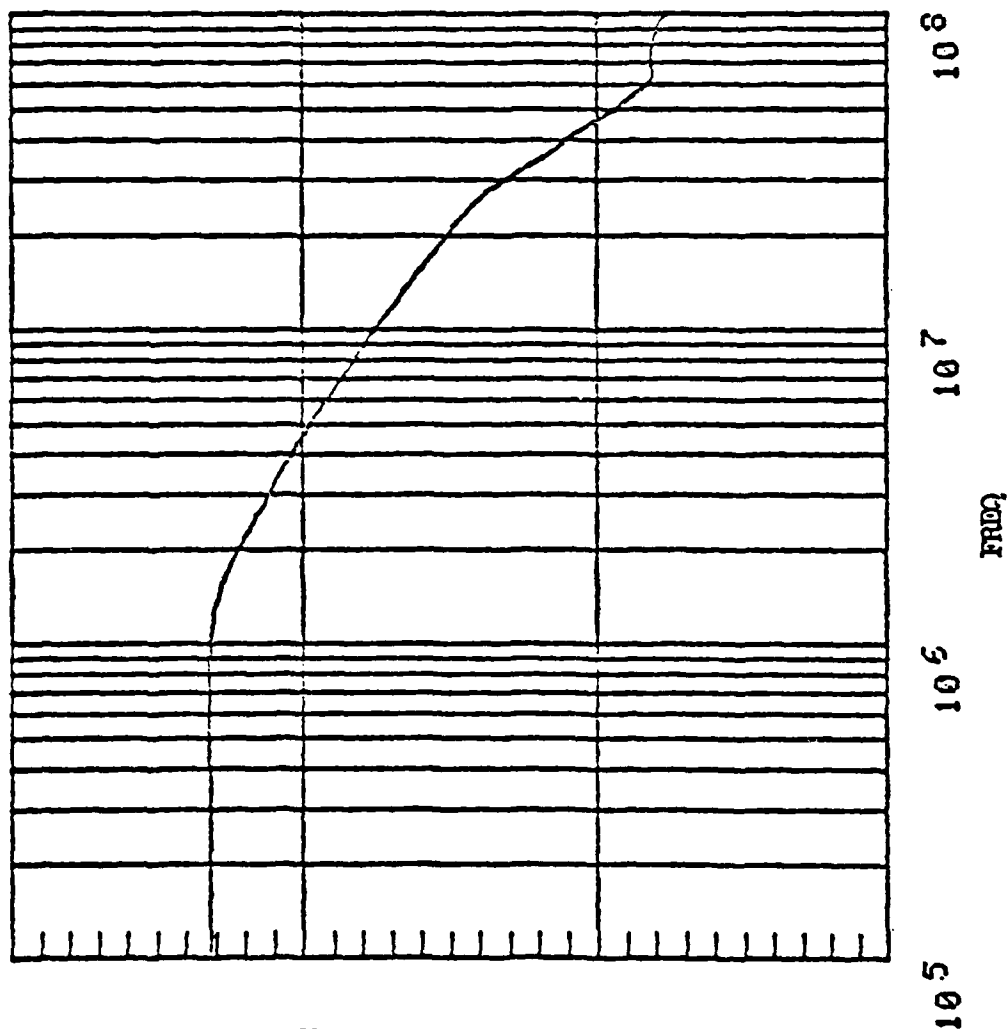
$\times 10^2$

TRANSMITTANCE 1.000

IN
DB

0.000

-1.000



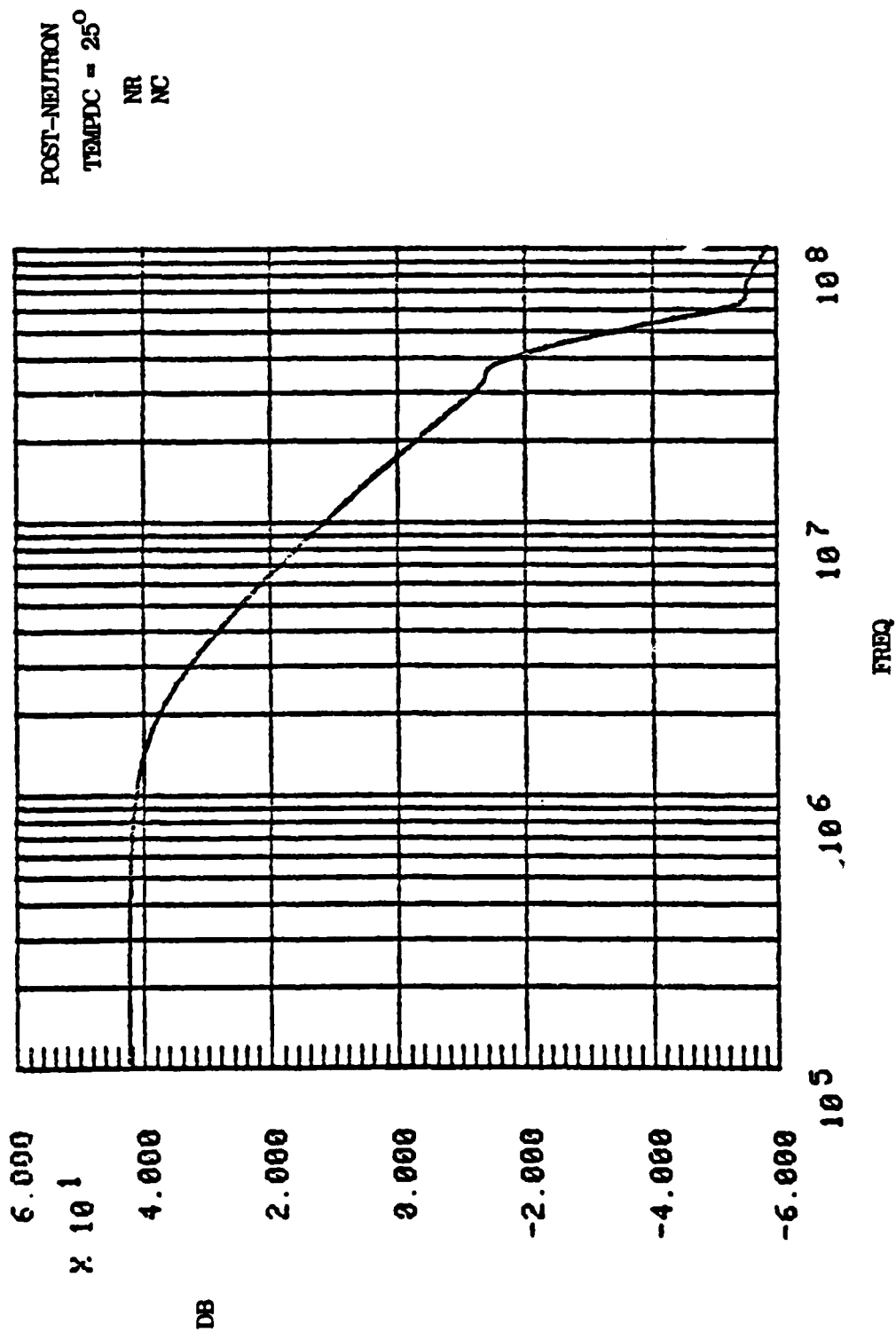
POST-NEUTRON

TEMP = 25°

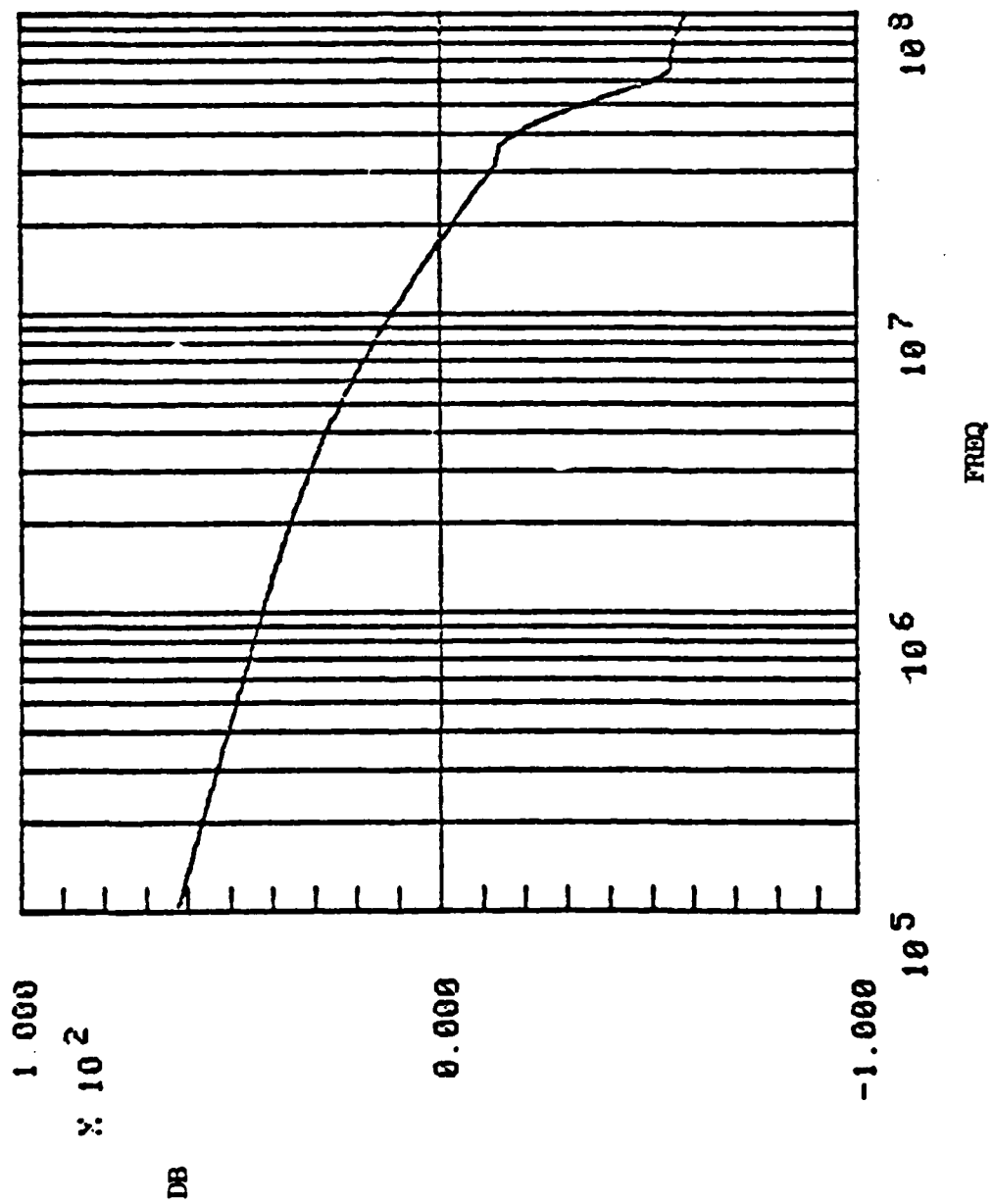
NR

NC

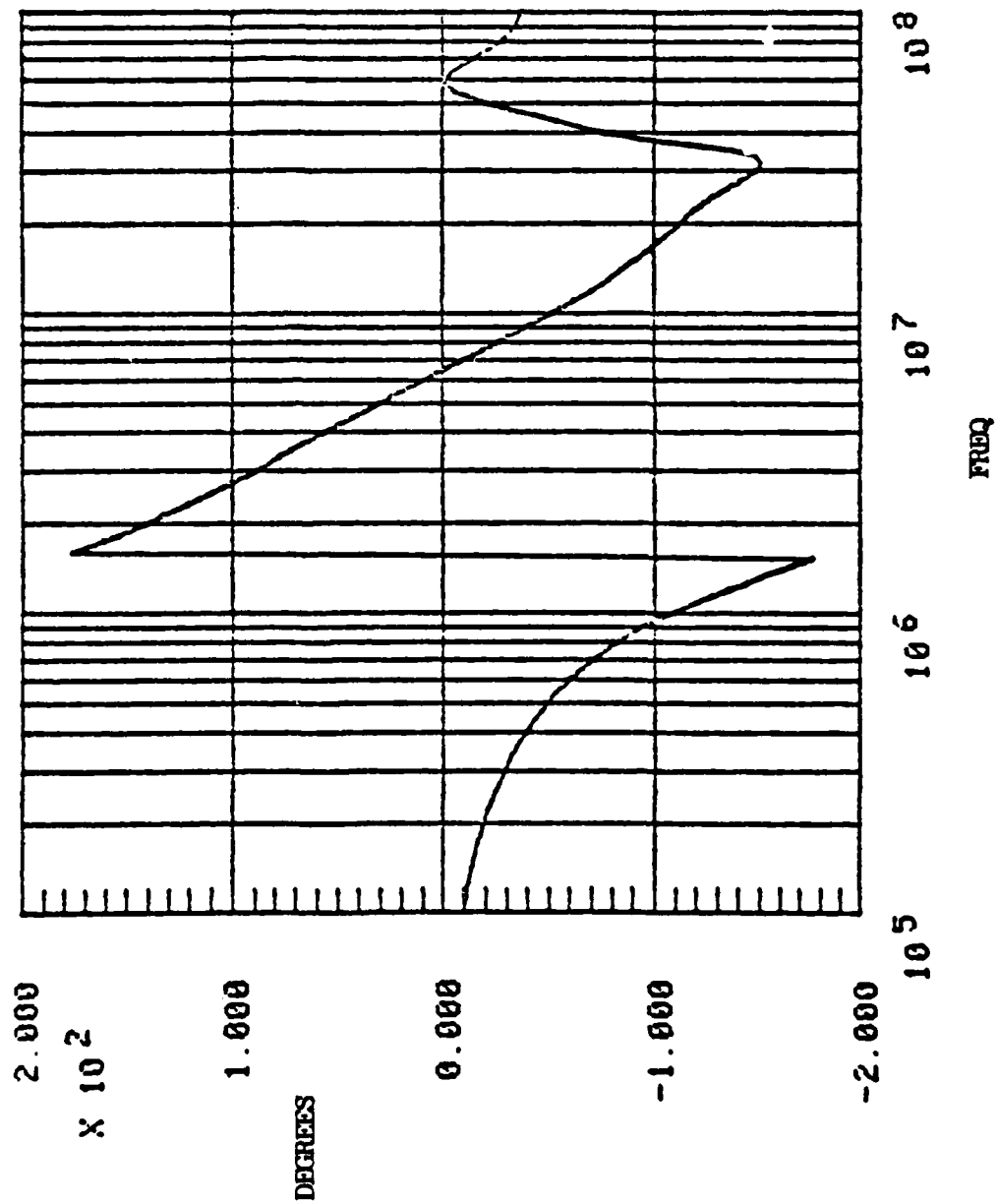
A₂ CLOSED-LOOP GAIN



A_2 OPEN-LOOP GAIN



A₂ OPEN-LOOP PHASE



TEMPDC = 25°

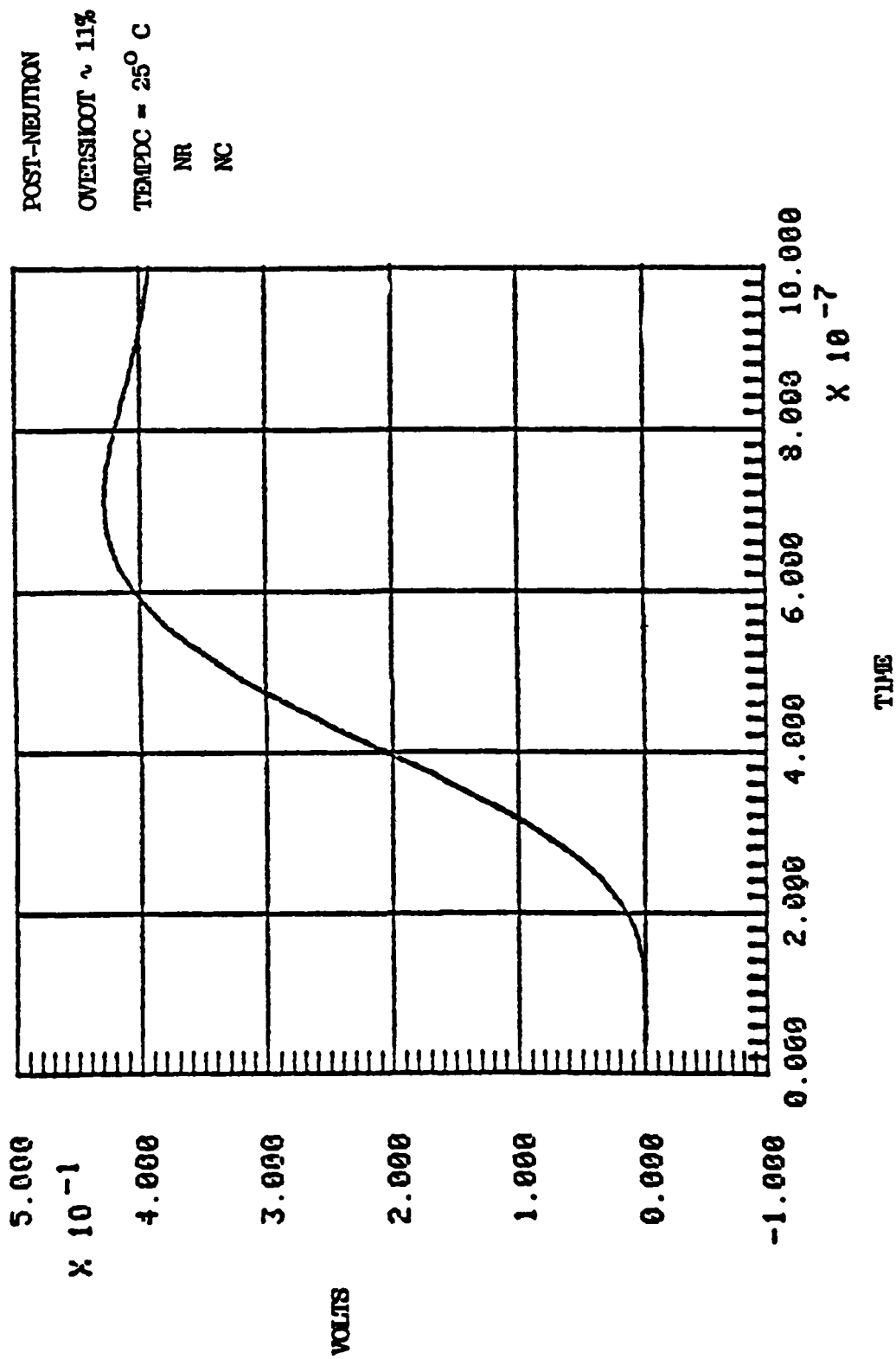
NR

NC

$\phi_m = 70^\circ$

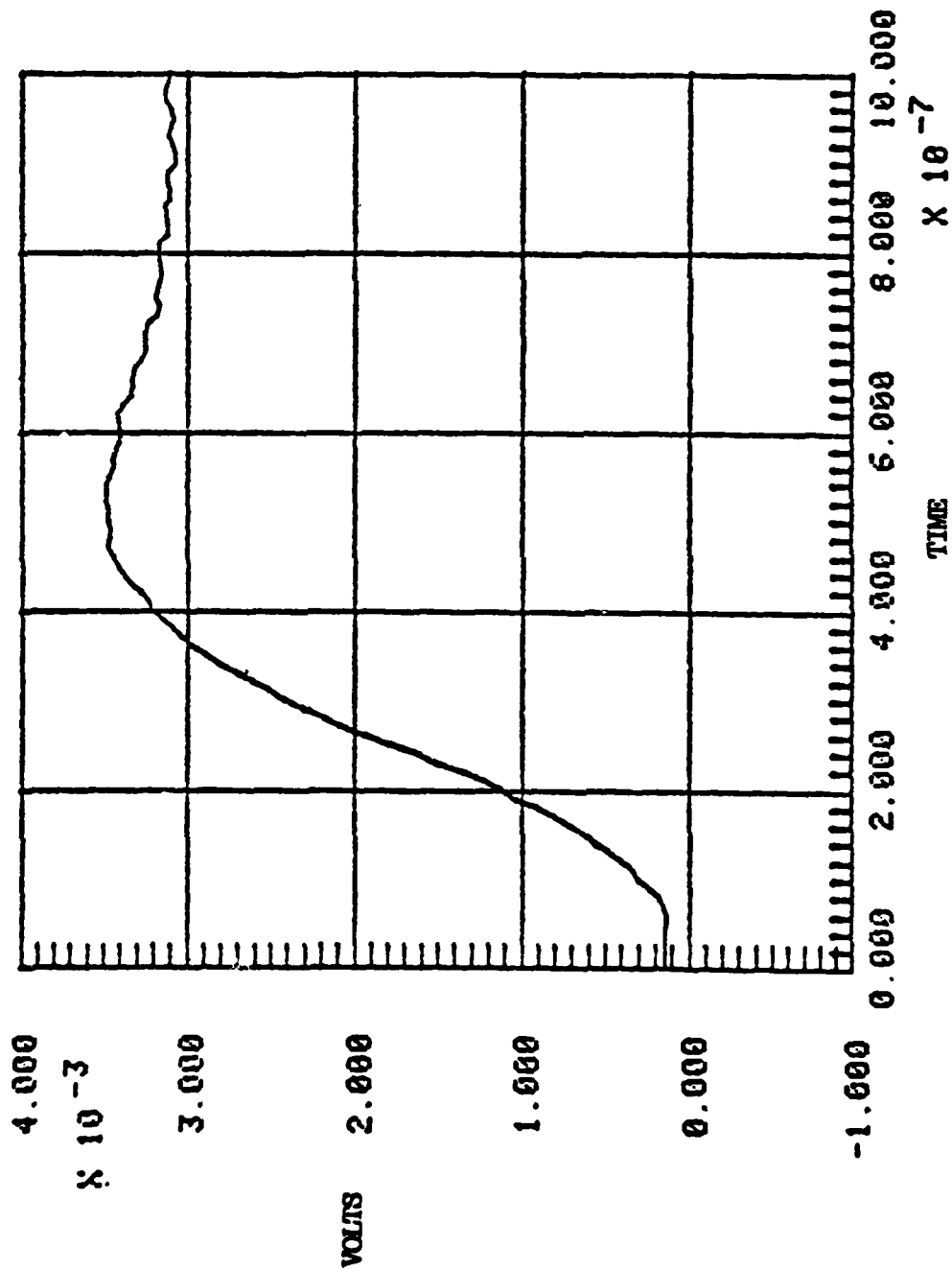
OVERALL STEP RESPONSE

100 NA STEP



A₁ STEP RESPONSE

100 NA STEP



POST-NEUTRON
 OVERSHOOT ~ 11.3%
 TEMPDC = 25°C
 NR
 NC

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APPENDIX 4.0

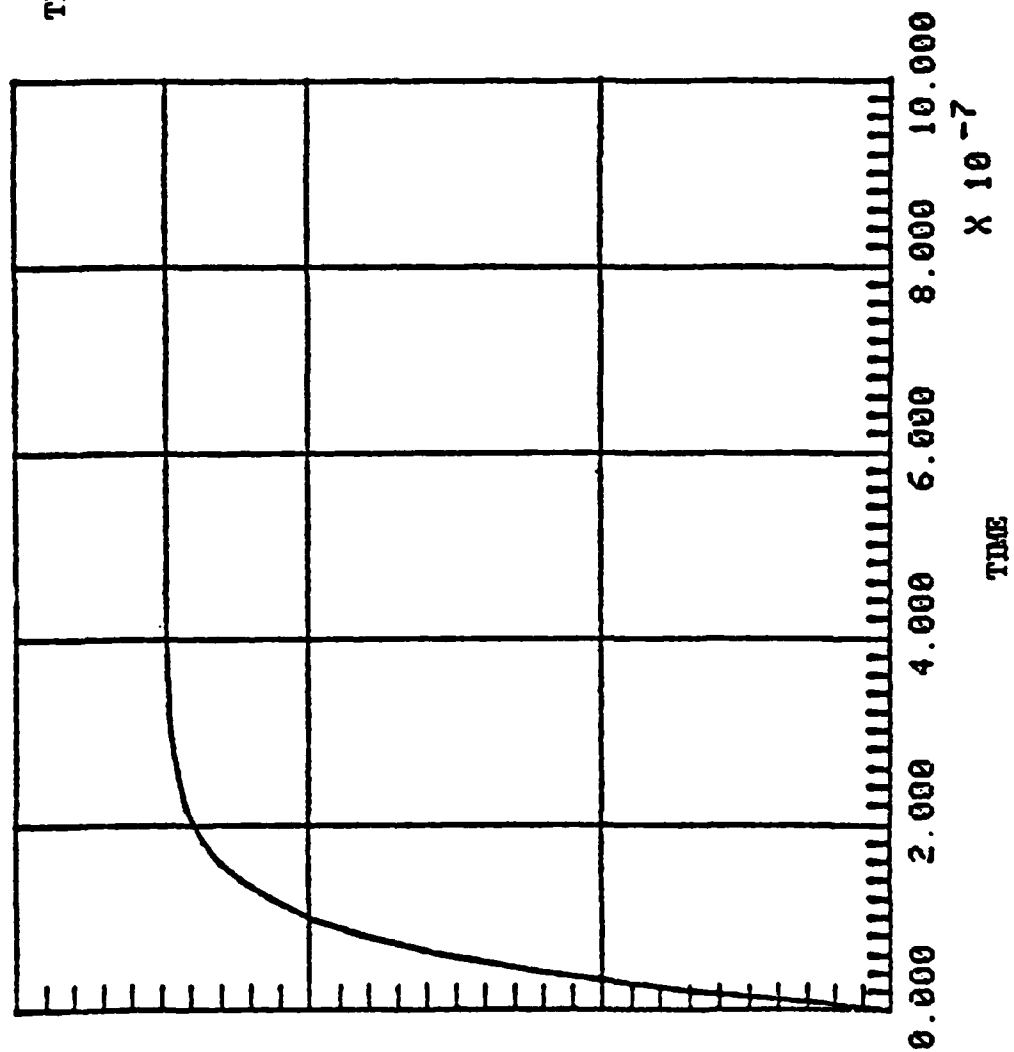
NOISE SIMULATIONS

4.1 TRANSIENT GAMMA

4.2 THERMAL NOISE

TYPICAL TRANSIENT GAMMA STEP

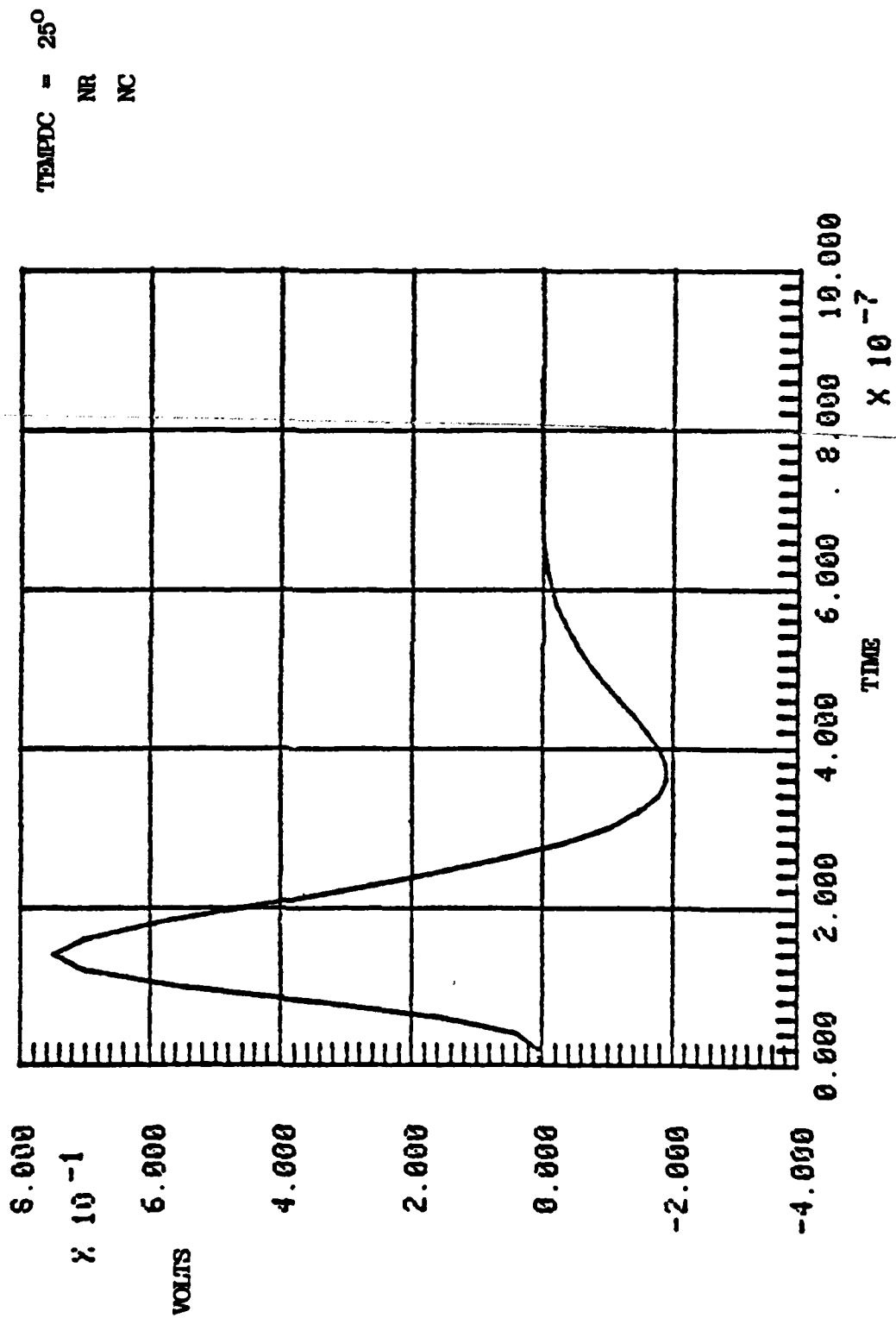
PHOTOGENERATOR CURRENT



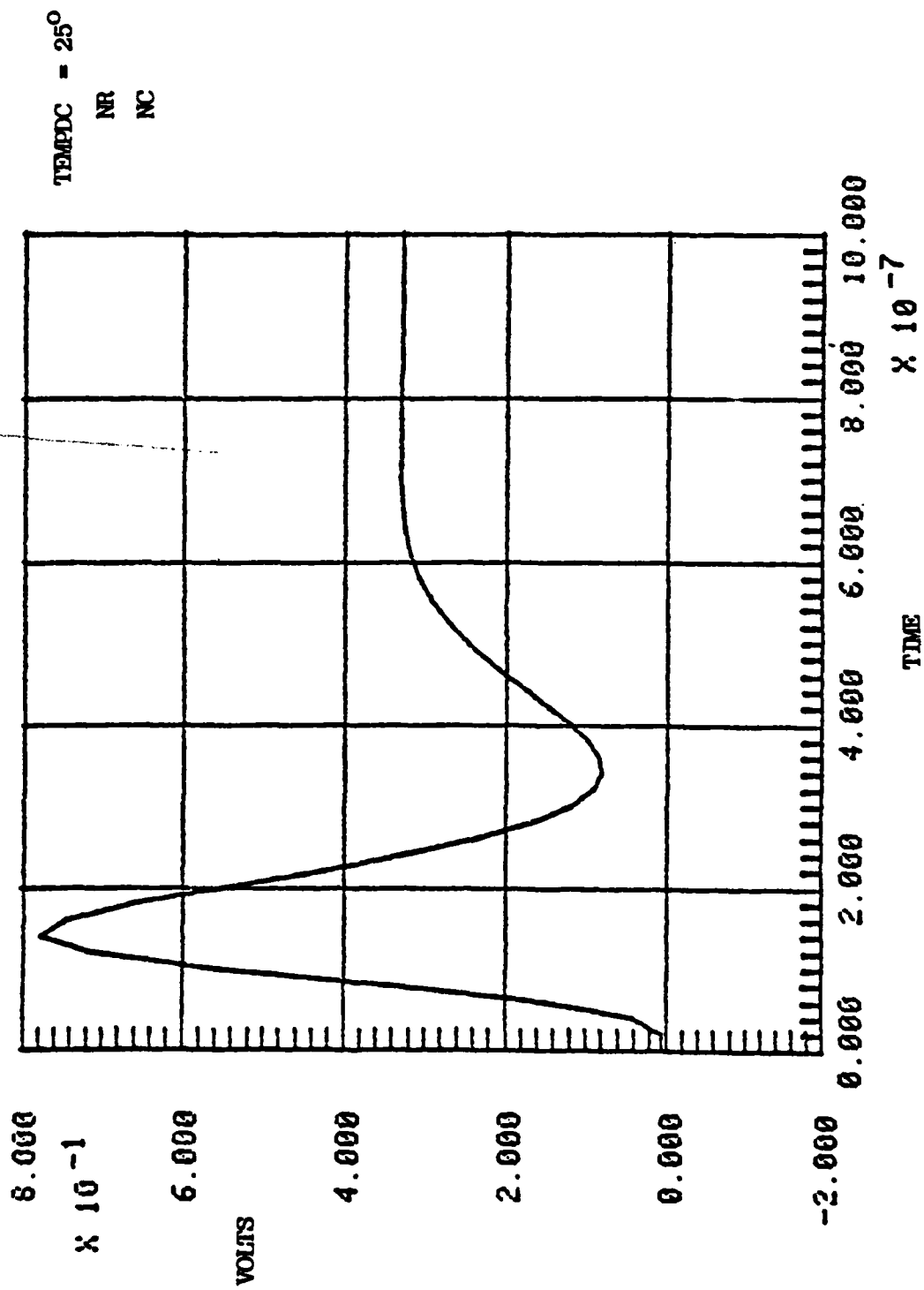
TIME CONSTANT
 $\tau = 60 \text{ NS}$

I_{pp}

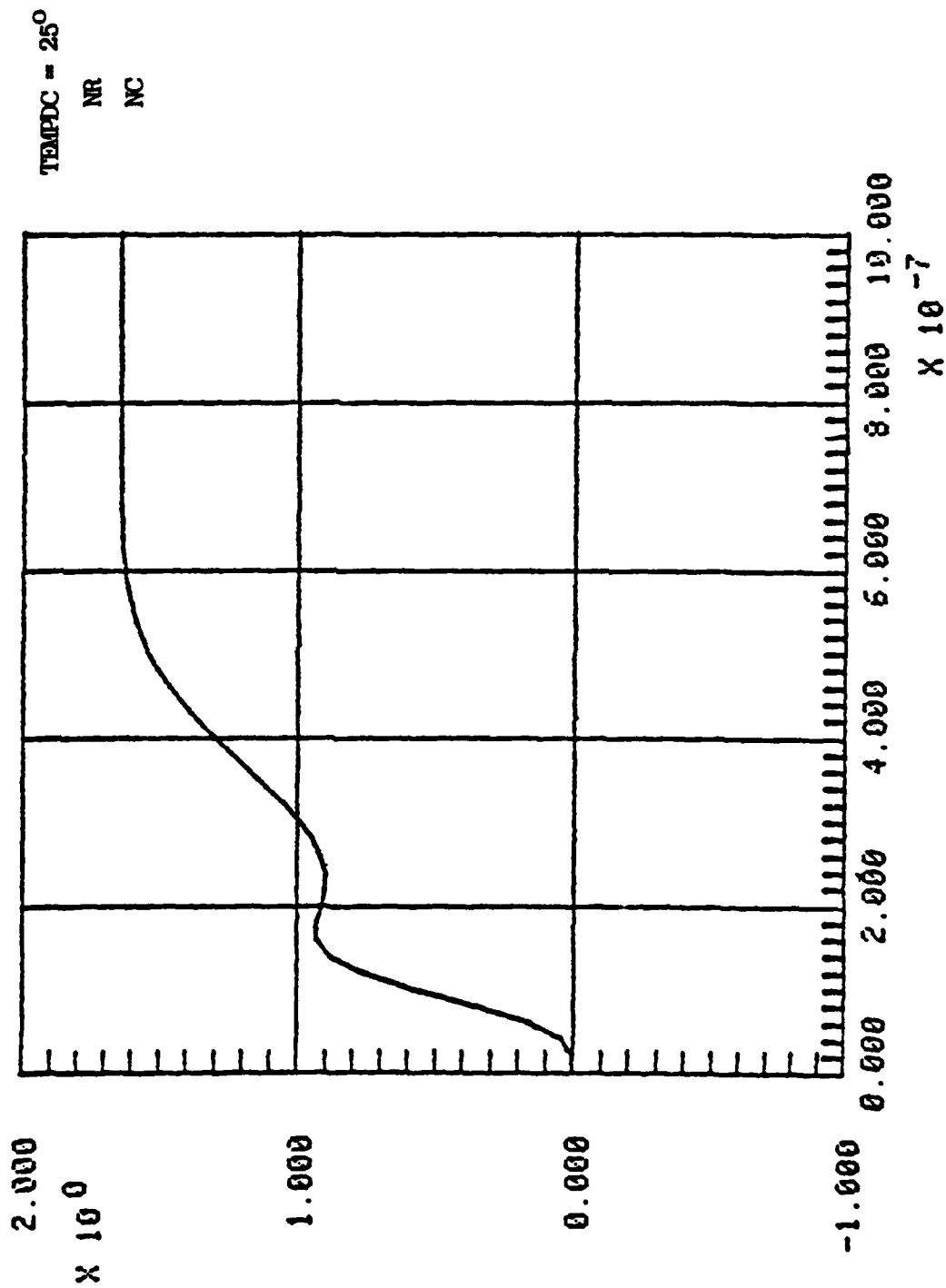
δ RESPONSE
(PERFECTLY MATCHED PHOTODIODE I_{pp})



γ RESPONSE
(1% MISMATCH IN PHOTODIODE I_{pp})



δ RESPONSE
(5% MISMATCH IN PHOTODIODE I_{PP})



OUTPUT THERMAL NOISE VOLTAGE SQUARED

3.000

$\times 10^{-11}$

V_{OUT}^2

2.000

1.000

0.000

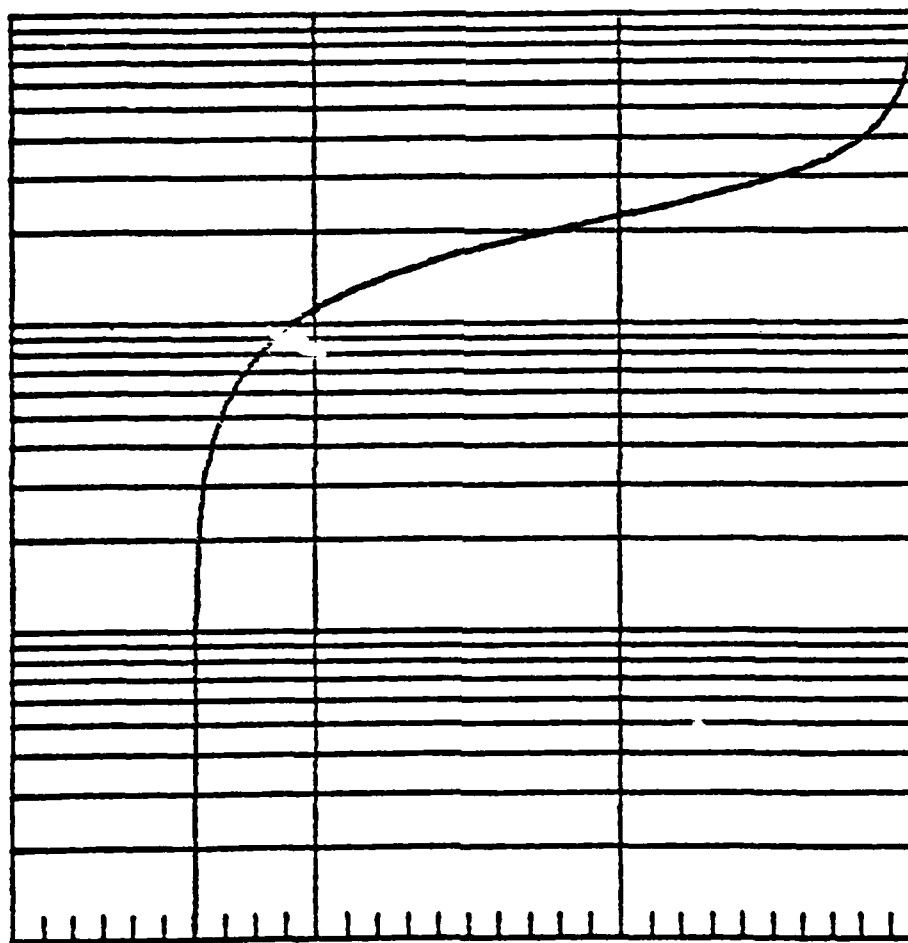
10^4

10^5

10^6

10^7

FREQ



TEMPDC = 25°

NR

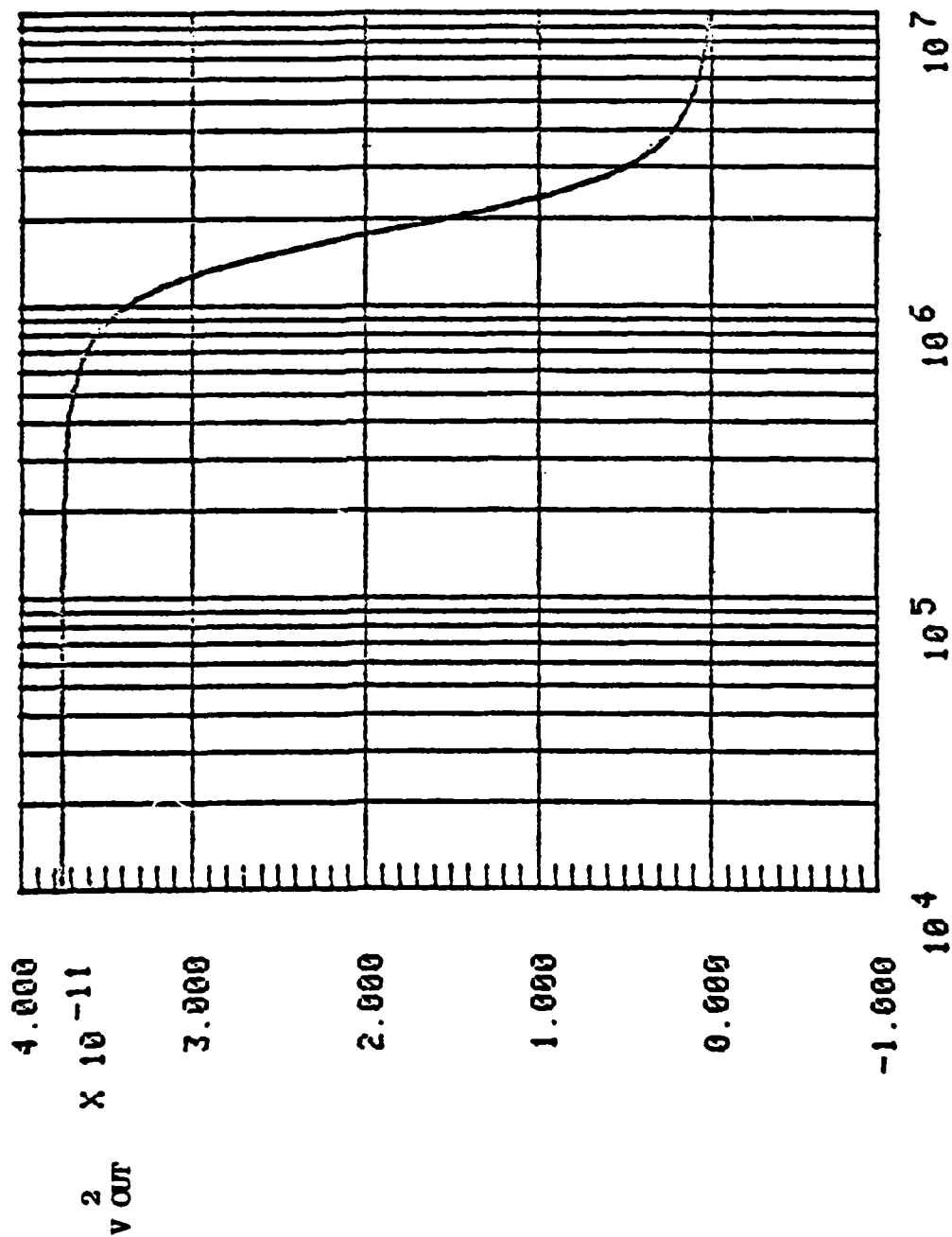
NC

TOTAL OUTPUT NOISE VOLTAGE IS

= $(2.4 \times 10^{-11} \bullet 2 \text{ mHz})^{\frac{1}{2}}$

= 7 MILLIVOLTS

OUTPUT THERMAL NOISE VOLTAGE SQUARED



TEMPDC = 125°

NR
NC

TOTAL OUTPUT NOISE VOLTAGE IS

$\approx (.375 \times 10^{-11} \bullet 2 \text{ mHz})$

$\approx 8.7 \text{ MILLIVOLTS}$

OUTPUT THERMAL NOISE VOLTAGE SQUARED

3.000

$\times 10^{-11}$

V_{OUT}^2

2.000

1.000

0.000

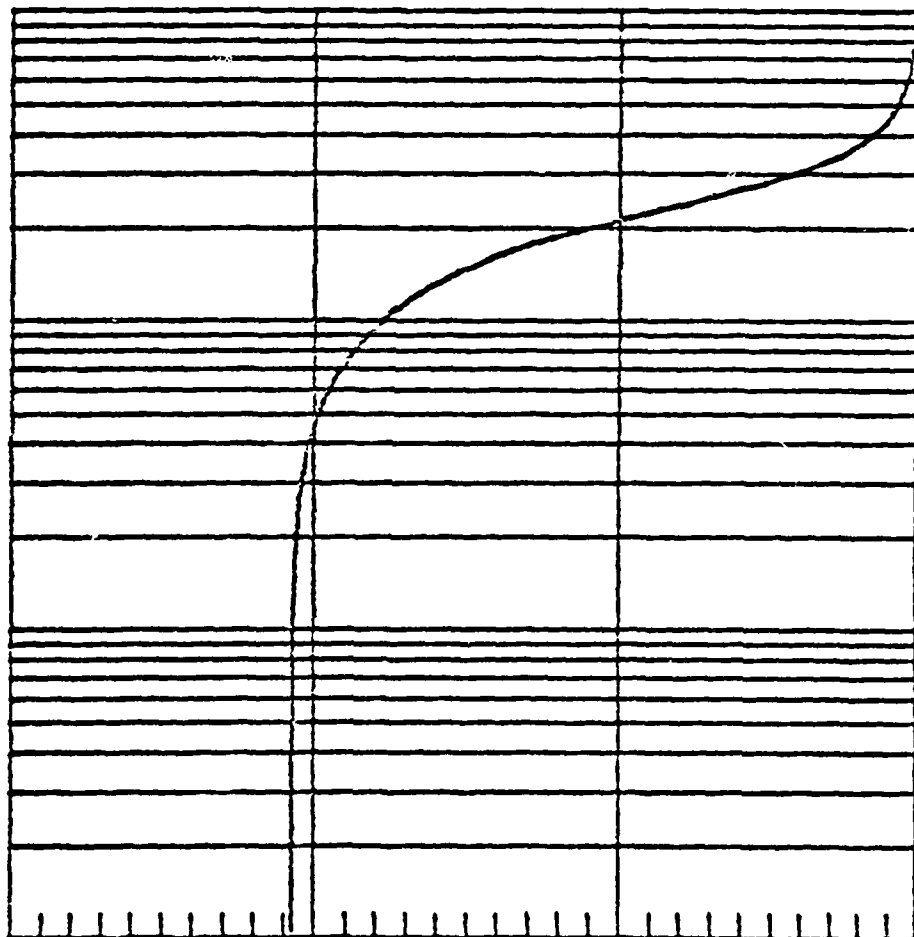
10^4

10^5

10^6

10^7

FREQ



TEMPDC = -55°

NR

NC

TOTAL OUTPUT NOISE VOLTAGE IS

= $(2.07 \times 10^{-11} \bullet 2 \text{ mHz})^{\frac{1}{2}}$

= 6.5 MILLIVOLTS

AD-A112 258

HARRIS CORP MELBOURNE FL

DINS FINAL REPORT.(U)

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F/6 9/1

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DNA-5597F

DNA001-78-C-0356

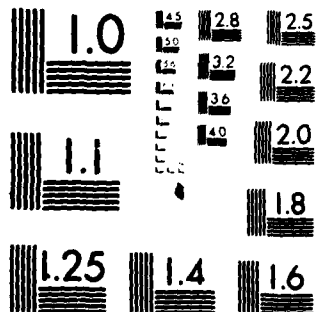
NL

3
4
5



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